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Applications of Chemistry to the Useful Arts being the substance of a Course of Lectures delivered in Columbia College, New-York, by James Renwick, Professor of Natural Experimental Philosophy and Chemistry.

V.

APPLICATIONS OF HYDROGEN, CARBON, AND THEIR COMPOUNDS.

IMPROVED MODES OF PREPARING CHARCOAL.

AUTHORITY.—DUMAS· Chimic appliquee aux arts.

In consequence of the great waste of charcoal, in the usual mode of preparation, and the entire loss of the volatile matter, two modes have been contrived, in either of which the quantity of charcoal obtained may be almost as large as in iron cylinders, and the volatile matters may be collected.

The first of these is best suited to the hard woods which contain but little sesinous matter. This operation is performed in a kiln of the shape of a cylinder, or rather a truncated cone, whose larger base is uppermost. It may be built of sods or tenaceous earth above the natural surface of the soil, but may be more conveniently excavated to such a depth that the earth thrown out may serve to form the upper part of the enclosure. In the only instance in which we have seen it employed in this country, namely at the West Point Foundry, the excavation is lined with brick.

In order to admit air to the kiln, when made by excavation, for the purpose of maintaining the combustion, tubes of earthen ware or cast iron, are carried down from the surface of the ground to the bottom of the excavation; these lie behind the lining, and are either passed through it near the bottom, or enter small brick vaults, which communicate with the interior of the kiln. The kiln may be closed at top by a cover made of sheet iron, to support which when the lining is not of brick, a ring of bricks must be placed around the top of the excavation. The cover must extend on all sides three or four inches beyond the opening of the kiln, in order to have a sufficient support. In this cover there are several openings, one at the centre, the others near the circumfrence. Through each of these a short tube or flue of sheet iron passes, and the several tubes are furnished with stoppers of iron.

The size described by Dumas is 10 ft. (French) in diameter, and nine feet deep. The central tube is nine inches in diameter. The number of these at the circumfrence is four, each four inches in diameter.

That used at the West Point Foundry is 12 feet in diameter and 9 feet deep.

In order to condense the volatile matter, one opening is made in the lining near the top of the kiln to which a tube of cast iron or earthenware is applied. This tube communicates with a small chamber built of brick, about 18 inches long, a foot in width, and 15 inches high, entering about the middle of its height. From the top of this chamber, proceeds a pipe of sheet iron, which after rising vertically 4 or 5 feet assumes a horizontal direction for about 15 feet more; at this distance there is no fear of fire, and the rest of the pipe may be of wood. The extension of the pipe communicates with a condensing apparatus, on the principle of Woolf, but which may be formed of common barrels.

In charging the kiln with wood, a post whose height is equal to the depth of the excavation is set up in the middle, and supported in its place by a heap of fragments of charcoal. A number of the larger logs are chosen and laid on the bottom of the kiln in such a manner as to form rudiating flues terminating at the places when the air tubes pass through the lining. Across these a horizontal layer of logs is laid. The radiating logs mnst neither touch the post or the lining of the kiln, the secondary layers extend from the one to the other Layers are then placed in succession in

such manner as to leave as little empty space as possible, particularly near the cir cumfrence, until the kiln is filled. The kiln having been charged, the post is drawn out of the middle, the cover set in its place, and coated to the depth of not less than two inches with dry earth.

The stopers being withdrawn from the flues in the cover, lighted charcoal is pourd down through the middle tube; this falls through the space left by the post, to the heap of charcoal by which it was steadied, and sets it on fire. The central flue is then tightly closed, in order that the draught may be directed toward the outside of the mass of wood. In order to make the joint of the stopper tight, it is luted with plastic clay. The other flues begin to discharge smoke, which is surrounded by flame. As soon as the flame ceases to have a blue color, and becomes white and clouded, the flues have their stoppers loosely applied to them, and the openings of the descending air tubes are diminished. The draught will thus be directed to the condensing apparatus. But if the collection of the acid be not intended, the tubes in the cover are but partially closed. The combustion may be regulated within the kiln by the air tubes and those in the cover. Thus, too rapid an action in any one part may be checked by completely closing the several air tubes and the opposite flue; and if it be too slow, these must be opened as far as possible until the action be restored.

For a kiln 10 by 9 the operation occupies from 60 to 80 hours, and is known to be complete when the upper layer of wood appears to be incandescent; when this has taken place, the stoppers of all the openings except that of the central flue are removed for a short time, and a quantity of hydrogen will be expelled which if does not injure the quality of the charcoal, would render it less saleable. As soon as the peculiar flame of hydrogen ceases, all the openings, both of the air tubes, and flues, must be closed by shuting their stoppers with clay, and covering them with caps of sheet iron containing clay. The dry earth is removed from the cover, and it is plastered with earth mixed with water. The charcoal thus shut up will take 60 or 80 hours to cool.

A plan and section of this description of kiln is represented in Fig. 1, 2, 3, 4 and 5.

Fig. 1 and 2. Being plan and section of one formed in an excavation, and

Fig. 3 and 4. Of one built above ground.

Fig. 5. Cover of sheet iron applicable to either.

A. Interior of kiln.

B. Wall or lining of earth.

C. Chamber in which the tar may be condensed.

d. Pipe leading to the condenser for pyrolignous acids.

e, e, e. Air-vaults.

f, f, f. Openings by which the external air is admitted.

At the Bennington Furnance, a kiln of similar form was constructed of brick, above the level of the ground and covered by a permanent dome of brick. In the wall a door was left for the introduction of the wood and this was subsequently bricked up. Vents were formed by leaving bricks loose in the wall and when the process was complete the fire was extinguished by means of water. An unexpected benefit was found to arise from the latter operation, for the coal becoming charged with aqueous vapour, was as fit for immediate use, as that which had been prepared for several months.

It is estimated that the product of kilns of this kind in France is about 25 per cent. more than in a coal pit. The experiment at the West Point Foundry was more advantageous, the product having 50 per cent. more than was obtained in the usual method. In France the main object was the pyrolignous acid, which at West Point was neglected, and this difference in the object will account for the difference in the results. The mode of placing the wood was also different, the French using that which has been described above while at West Point it was placed vertically.

In the pine forests of Sweden, an apparatus better suited to the collection of the turpentine that kind of wood furnishes, has been invented by Schwartz. This kiln is composed of a vault, built of brick or silicious stone laid in a mixture of clay and sand. Common mortar must not be used as it would not only be affected by the heat, but would be completely destroyed by the pyrolignous acid. The vault is closed at each end by a vertical wall of the same kind of masonry. The floor of the kiln is of earth, and has the figure of two planes slightly inclined, and meeting in a gutter in the

Fig. 1.

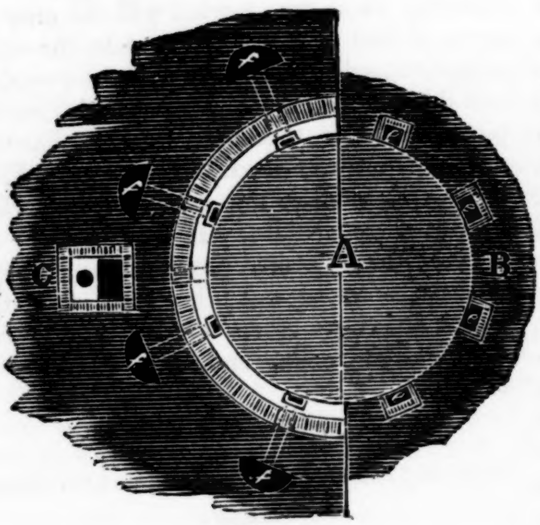


Fig. 2.

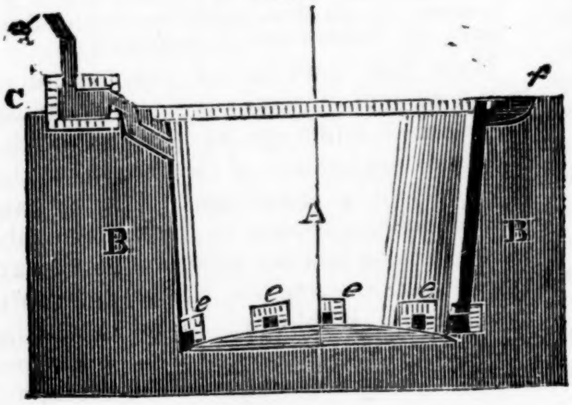


Fig. 3.

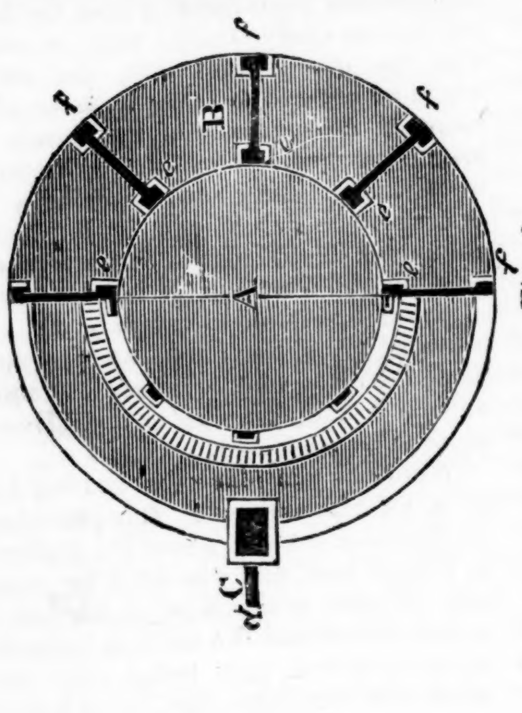


Fig. 4.

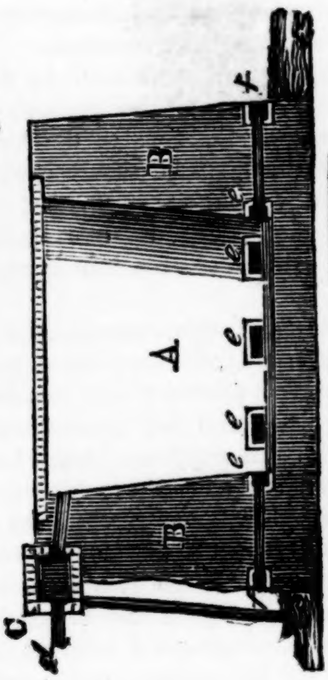
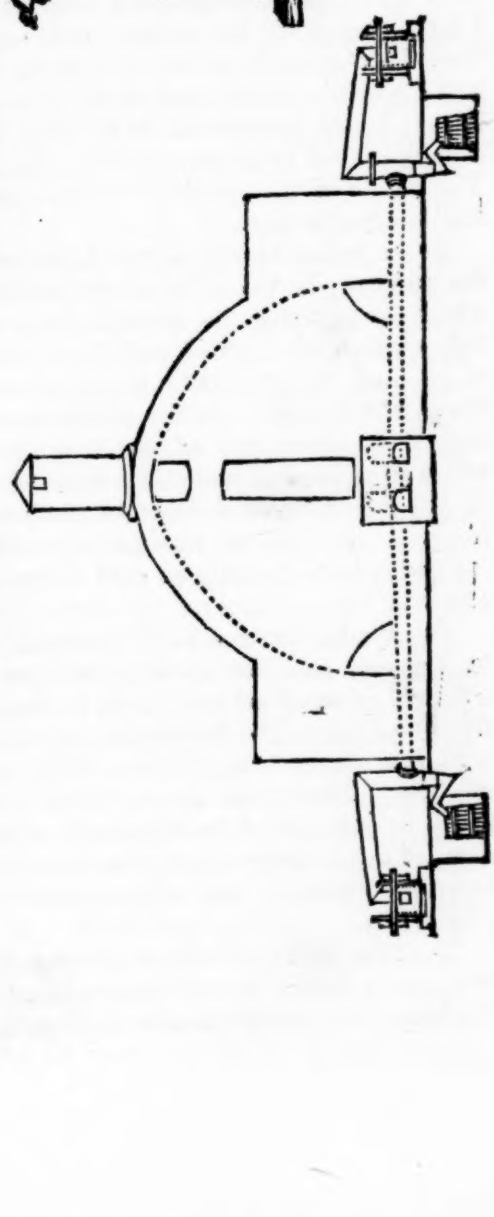


Fig. 5.

Fig. 6.



middle of the longer sides of the vault. In each end wall are two fire places, and in one of them are four openings for introducing the wood and withdrawing the charcoal. The smoke and vapour are carried off by flues of cast iron at the level of the ground, and proceeding from the middle of the larger sides of the vault; these terminate in channels where the vapour is condensed and which convey the smoke to two vertical chimnies. A section of this kiln is represented in Fig. 6.

The advantage of this arrangement is, that no air can enter the kiln without passing through the fire places which are kept full of burning fuel; and that the fuel which is best suited for this purpose, (small branches and twigs,) is useless in making charcoal. In placing the wood, the pieces are laid parallel to the largest sides of the vault, and in such manner as to leave as little space as possible except in the neighbourhood of the flues, which must be kept free for the escape of the smoke and vapour. Two days are sufficient to convert the wood into charcoal, and the end of the process is known by the appearance of the blue flame of carburetted hydrogen at the chimnies. The whole of the openings are then closed and luted with clay.

At the end of two days, two holes left for the purpose in the arch of the vault, but which have during the process been carefully closed, are opened and water thrown in to cool the charcoal; these holes are then closed again. At the end of three or four days more, one of the doors in the end wall is opened and more water thrown in, but the charcoal will not be ready to be removed until all the external parts of the apparatus have become as cold as the surrounding air.

This kind of furnace has been much used in Europe, and the quantity of charcoal obtained is one third more than is obtained from coal pits. The turpentine and arcetic acid are also saved, which in other cases are lost. There can be no doubt that it might be introduced to advantage in those parts of our country where iron is manufactured by means of charcoal prepared from pine wood.

In using kilns of either description it becomes a matter of calculation whether it be cheaper to manufacture the charcoal in the woods in the usual manner, or to carry the wood to the kiln. The weight of the charcoal to be transported will be only 17 parts of that of the wood; while the charcoal obtained by the kilns will be certainly one third more than that procured from the pits. It must therefore appear that the value of the additional charcoal shall be at least equivalent to the cost of transporting the wood to the kiln. It is also to be remarked that charcoal prepared on the spot where it is to be used is better than that which has here been handled and carried over rough roads, and that all waste is avoided.

VENTILATION OF THE HOUSES OF PARLIAMENT.

(Extracts from the Evidence of Dr. Reid, F. R. S. E., President of the Philosophical Society of Edinburgh, &c., before a Select Committee.)

Have you at all turned your attention to the subject of ventilating and warming large public buildings, as well as to the practical application of acoustics to the construction of buildings? I have paid considerable attention to both these subjects; I have had my attention particularly directed towards the subject of ventilating large buildings; more especially from the circumstance, that on some occasions in my class-room there are 2,000 experiments performed within the hour, and unless every thing were managed with the utmost precision, the student would be obliged to retire from the class-room in consequence of the fumes that are disengaged. The means I adopted were simply taking advantages of a current which is determined by means of a column of heated air; a large furnace is kindled, and wherever it is necessary to carry off fumes, or to ventilate an over-crowded or heated room, an aperture is made into that vent, or otherwise connected with it leading the air or fumes from the place to be ventilated.

Where do you place the heating apparatus for that purpose? It is placed upon the floor—a few feet above it; it plays into a large vent, and wherever an opening may be made in that vent, an internal current—a current into the vent—is immediately set in motion, care being taken at the same time that there shall be as free room

given for the entrance of fresh air at a different place, as there is for the exit of the heated air.

Would you advise that such an apparatus should be placed on the floor of the House of Commons, which is the building to which the Committee is at this time devoting its attention?—By no means; I would have it worked in an independent apartment. It is fitted up on the floor in my class-room because we take advantage of the heat; we find we can carry on a number of furnace operations, of a particular description, with a moderate heat, with the same fire which induces and regulates ventilation; that being no object whatever, for the purpose required in the House of Commons, it would be better to have the furnace in another place where it would not be inconvenient.

Whether you place the apparatus below, or in or above the room to be ventilated, it is immaterial?—It is of no great consequence; but this is to a certain extent of consequence, that if placed in such a manner, that there shall be a current, we may draw the air from the House of Commons, not merely by the vent, but by the lower part which supplies the fuel of the furnace with air, thus furnishing it with additional power; I wish to take advantage not only of the current which is made to ascend from the lighter current produced by the heat, but also to draw from the House of Commons the air that feeds the fire.

If the furnace were situated in an apartment immediately over the House of Commons, the air from the House of Commons would rise to it and create that draught, would it not?—It might create a little draught, but the power as produced by the furnace is dependent upon the light and expanded air rising from the fire; at times we have the air warmer without than within, and were it not for the heat actually developed by specific combustion, our currents might sometimes be reversed.

But under any circumstances, do you propose for the purpose of ventilation to have the vent tube placed in the chamber to be ventilated? There is not the slightest necessity for it; if a communication is made by a tube towards the vent, that is all that is essential.

From whatever place the supply of air is taken, ought it not to be a spot freely open to the action of the winds and atmosphere? It would be preferable.

Do you contemplate that when the House is crowded the ventilating apparatus should also be used at the same time?—It should be ready for powerful action at all times; but I would not propose that the ventilating apparatus should be brought into full action until it was absolutely necessary; it could be worked always in such a manner as the varying circumstances of the case might require; I should of all things wish to avoid any accumulation of bad air, so that it became necessary to use the ventilating apparatus with great power; but I would not put on the ventilating apparatus until Members actually began to assemble, and from that moment the ventilating apparatus being in action, it would be better to keep up the purity of the atmosphere by a general and equal flow, than by allowing bad air to accumulate and then working it with great power. In many of the buildings which I have seen there is not nearly sufficient exit and entrance provided for the quantity of air required, so that when the windows are afterwards thrown open, cross draughts are induced in every direction.

It is your opinion, that in constructing the building generally, reference should be had to the position of the doors and windows, as well as to any ventilating apparatus that may be applied to secure good and proper ventilation?—The utmost attention, I think, should be paid to this, if it be intended to use them at times to assist the ventilation; but I would strongly recommend that they should never ventilate at all by doors (that there should be double doors,) nor by the windows, except under the most peculiar circumstances. There might be arrangements made with advantage for throwing open the room by doors and windows to a certain extent; but if provision be made by other means, the ventilation will be completely under control when there is a power which can be regulated. The moment we begin to ventilate by doors and windows we may refresh those who are very near, but we have a sweeping current that runs in a particular direction, and there is no equality of ventilation; some may be refreshed or perhaps injured by the draught under such circumstances, but there will be no equality of dif-

fusion; and others may receive no fresh air at all.

Do you suppose that the same ventilating apparatus might be made applicable to the House and the Committee-rooms of the House in the morning?—That is what I should wish to see done in every large establishment, and not only the ventilation of the large room, but also tubes connected with the smaller apartment, and valves are ranged so that the apparatus might work exactly in the same manner as water or gas in pipes laid through a city. If there be one great chimney or ventilator through which every thing is to pass, by opening or shutting a valve in every individual room or apartment, be it what it may, any degree of ventilation can be commanded that is required. But a general difficulty has arisen in consequence of these provisions in most places not having been made any thing to the extent that is absolutely necessary; consequently, when in full action, the doors and windows are thrown open all at once, and it disturbs every thing like unity of operation. There is another thing connected with ventilation as conducted by heated air, namely, that it is not liable to the noise produced when the ventilation is induced by the working of a fanner or other common mechanical power put in action by machinery. Further, the same power dependent upon the application of heated air will also enable cold air to be thrown in whenever it may be necessary, which may be artificially depressed in its temperature in warm seasons; this would give great relief when there are months together of continuous hot weather. I should wish to see, not only arrangements for renewing air and warming it in the winter, but for cooling it in summer, which I think might be done with very great facility.

You do not contemplate the principle of regulating it by a self-regulating action?—I should almost doubt whether that could be done; I do not say it might not ultimately be effected; but I have seen such a great number of ventilators fail in this respect, being subject to such a number of influences, that unless we were almost to attribute to them a kind of mental reaction, they could scarcely adapt themselves with precision to the varied circumstances under which they must act; but any ordinary attendant may be taught, by a little attention to the thermometer and the number of Members present, to increase or diminish the working of the apparatus to any extent.

A thermometer might be placed in some great thoroughfare, so as to be open to inspection?—Yes, it might be placed in the body of the House, so as always to be before the Members. One might easily be constructed for this purpose, both large and sufficiently delicate to be a constant check upon the ventilating apparatus; the usual register-thermometer might also be used, so that a most complete check may be obtained over the machinery, and the attendance of the person engaged in conducting it, at times when no one might be present to examine the heat, &c.

Supposing the thermometer rose very suddenly, do you think that then the apparatus you are talking of would rapidly reduce that apartment to a proper state of ventilation? It could be made to work to any extent. I may mention, on several occasions, gentlemen may have come in from at distance, foreigners and strangers, to see the working of my ventilating apparatus; when there was nothing doing in the laboratory, we have put on the fire with a few pieces of wood, in the course of five minutues we were able with that to bring it into such a state of activity that fumes produced in showing some experiments were carried with great rapidity by these ventilaors, which in the course of three minutes, would have filled the room to such an extent that we should have been obliged to go out, had they not been in action.

With regard to one apparatus being efficient in ventilating the new Houses of Parliament, and all the Committee-rooms and other buildings, should you adduce that as an advantage in point of economy, or in point of general equability of ventilation? In every point of view; better than having more than one, for a small power is quite sufficient to work a great number of small ones.

Taking the Houses of Parliament, without going to the other rooms, suppose there are thirty Committee.rooms, would you say that one apparatus should be sufficient to ventilate all this over a large surface of ground, as well as the House of Commons and the House of Lords in the same way?

They might all be ventilated by one large furnace.

It is rather a matter of judgment, arising from the extont and number of apartments, than any thing else, as to how many of those furnaees you would have? It may be more economical to have two large ventilating furnaces if the rooms are very much apart, than to carry all the independent flues a very great length.

Can the tubes be conducted to any considerable distance from the room to the apparatus? To any length almost; I have seen them conducted hundrds of feet without any material difference.

You would not have the tube of so large a diameter as to occasion inconvenience in making the building originally? A tube so very large and inconvenient would not be required; but every thing would depend on the primary arrangement made by the architect; it is not a thing to be added, but to be seen from the foundation, and all those flues could be carried under ground, and there would not be the slightest necessity for one to be conducted in any way where it would interfere either with ornaments or any thing connected with the building. You may carry the air down as easily as you can carry it up. I admit, indeed. that the movements induced during the rarefaction of air are such that it would be more easily carried up than otherwise; but yet, with furnaces, the difference is not so great as to make a decided alteration in any plans connected with the arrangements of the ventilating tube.

You would be more liable to a return current in case of any mismanagement of the tubes, in case you convey them down from the ceiling of the room? Yes, I admit that; but, at the same time, when the furnace is attended to with moderate care, I should not anticipate there would be any danger of those accidents occurring.

As to the admission of air for the House of Commons, how would you propose to arrange the tubes for its admission; would you distribute them over the floor, or would you admit the air at one great aperture?—I should prefer that the air were taken out at one aperture, but admitted by a great many, and broken as much in its impetus as possible by the division of the tubes, as far as that could be effected; and if no arrangement be adopted for preparing the air in its temperature before it be admitted into the House, which I consider the most effectual mode of conducting a proper system of ventilation, I should perhaps be inclined to prefer that the air should be admitted at a little height, than exactly on the floor or on the ground, for though the air be admitted from the floor in 10,000 little apertures, still there is some danger of the Members feeling the effect of the direct introduction of the cold air in very cold weather. This system must necessarily be considered defective, as the cold air, though broken in its force before it could reach the Members, would tend to carry along with it a portion of the respired air with which it must necessarily mix; whereas by introducing over the body of the floor the whole of the fresh air at a regulated temperature, air once respired would be carried away, and the atmosphere would never be of that oppressive character which often increases to such an extent in some buildings, where the respired air is not so easily carried away, as to produce a very powerful sedative effect, often accompanied by severe headache, more especially when it is necessary to maintain a continued and anxious attention to any subject under discussion.

The evils of a current of a certain velocity may be equally great whether the air be moist or dry?—There must be a difference there; a very dry current of air passing across the face may produce a very different effect from a very moist one; I would consider it of equal importance, indeed of much more importance to divide the current of air than of cold air, because when a current of cold air is introduced, it naturally falls down and diffuses itself; but if hot air be introduced from any particular source, and in great quantity at one place, that will rise in a stream to the top, without benefiting those in the body of the building. We have had remarkable instances of that in public buildings, which it was said could not be heated, though great sums were expended upon them. At a distance of twenty or thirty feet from the floor there might often be observed a stratum of air at a temperature above that of boiling water, while below the air has been disagreeably cold.

In the admission of warm air to supply the room, it would be necessary to distribute the apparatus evenly over the whole surface of the floor ?—As widely as possible.

And as numerously as possible ?—Yes, so far as it could be conveniently done, the heating surface on the floor could not be too extensive.

It is necessary to conduct the heated air over the whole surface of the floor, and not to trust to an apparatus radiating the heat? I should think it absolutely necessary to conduct the heated air when it is supplied in currents; but if you have different stoves heated by steam in different parts of the building, or surfaces of iron heated by hot water or otherwise, that may make a great difference. The great objection to stoves or large plates heated by water or steam, is the unequal currents which necessarily accompany them, and the return of respired air in a descending stream. In all lofty buildings, it is impossible to have that sweet and fresh atmosphere which might be so easily commanded in a less elevated apartment, where a stream of air might be made to rise slowly but continually from the floor to the top of an inclined roof, to be removed there by the ventilator. A lofty room is generally preferred, because, from the mass of air present, a long time is necessarily required to contaminate it; but when prolonged debates are carried on, it is evident that the very cause which prevents it from being contaminated to such an extent at first, will render it exceedingly difficult to renew the air when once it shall have been vitiated.

Would you propose to regulate the velocity of the air admitted by artificial means, or trust to its change of place simply by its altered gravity ?—I would propose to have every part of the ventilating apparatus under precise control, without that, it is utterly impossible to adapt the currents to the varying circumstances of the place; arrangements ought to be made to cut off the supply entirely, to exchange a pipe of cold air for the hot air, and, in short, to effect any change upon the currents we may wish at a moment's notice.

Those apertures might be so regulated, that a person sitting in another room, by turning a handle, might open or close the valves ?—Yes; it is easy to do that; at the same time it would be necessary to have them all under some general control or superintendence in case of their not acting harmoniously together.

From the American Journal of Science and Arts.

ACCOUNT OF AN AURORA BOREALIS, WITH A NOTICE OF A SOLAR PHENOMENON; BY CAPT. R. H. BONNYCASTLE, R. EN., TORONTO, UP. CANADA.

I. *Aurora Borealis.*

Having witnessed from the days of my boyhood, the splendid phenomena of the Boreal Aurora, in almost all the latitutudes under which it is usually seen, as far north as to have observed the sun at midnight, and particularly during a long sojourn in Shetland, where the people imagine, from its extremely swift changes and inexpressible vividness, that they can actually hear its rushings, I have ever been anxious to seize all opportunities of endeavoring to catch its Protean forms, and to describe them, in hopes that by exciting attention to facts concerning this wonder of northern skies, science might be more attentive to its appearances, and that at length it might become a portion of the duty of meteorologists to detail in their columns, all circumstances concerning it, which they might observe.

The Aurora in the high northern latitudes, when at its extreme, is almost dazzling, and the quickness of its motions approaches that of lightning. In other situations, it has also been observed to assume irised colors. But although all these combined are eminently wonderful, and strike the spectator with profound admiration and awe, yet perhaps the regions of Upper Canada, bordering on Lake Ontario,* exhibit, though not so splendid and varied a display of this mystery, yet one equally, or perhaps more, interesting to the philosopher. I have now witnessed the Aurora at Kingston for upwards of four years, and in a former volume of the Transactions, have described a magnificent scene, which occurred there two years ago.

During the winter months, on Lake Ontario, the Aurora may be said to be almost constant companion of the dark and cheerless nights, and it occasionally presents itself at all other times of the year, nor is it

* Not having observed it elsewhere in Canada, I speak only of locality as a personal observer.

in winter a mere display of a glorious phenomenon, the utility of which has not yet been exemplified by science, for it sheds a continued and pleasing light, which resembles that of the crepuscular. The light does not, as in Europe, emanate from the vivid streamers which dance over the starry floor of the heavens, in ever changing and inexplicable mazes, but proceeds from the northern horizon, over which a pale, luminous, low, and depressed arch, embracing an extent of from sixty to ninety degrees, is commonly thrown. This arch is generally luminous in its whole body, not on the rim or verge only, which fades away into ethereal space, but from its superior circumference to the chord formed by the horizon itself, and varies in its elevation, from ten to fifteen and twenty degrees. Wherever it embraces stars, these luminaries are either veiled or dimly seen, being strongly contrasted on a fine star light night, with their fellow orbs of the southern heavens, which appear to shine out with double brilliancy.

Within the space comprehended by this arch of light, continual changes are operating, if the Aurora assumes a splendid shape. Dark volumes of vapor, not like clouds, but blackening in a moment, rise and fall, whenever a ray or an interior arc begins to form, and it is remarkable, that this darkness usually accompanies the commencement of every change in the scene, thereby increasing the majesty and beauty, as well as the brilliancy of the spectacle.

But it is impossible for any pen adequately to describe a phenomenon, which is continually presented in these regions, and it is with diffidence that I continue a task imposed on myself. It will, therefore, be more satisfactory to detail the circumstances attending a very recent repetition of one of the most beautiful of those which have been seen at Kingston this winter, nearly the whole of which I saw, and whatever escaped me was related by a very accurate observer.

On the evening of the 11th of December, 1835, the sky, after the sun had sunk, was dark and gloomy, and although there were but few clouds visible, and the stars were rapidly brightening, a change of weather was apparent. Snow had fallen, for the first time, on Wednesday, the 8th, after a short space of great cold, to the depth of about five inches, and the thermometer had sunk afterwards to 16°, at which it stood on Monday, the 13th. On Tuesday, it rose to 30°, and rain in abundance falling, removed the snow entirely. It was exactly midway between the extreme cold and the thaw, that the Aurora took place, the thermometer at the time standing at about 26°, and the wind, a gentle breeze from the north west. The barometer stood at 29.9, at 9 P. M., at an elevation of forty feet above the lake, which is two hundred and nineteen feet above the level of the sea.*

Its first appearance, after darkness had completely set in, was by the luminous arch above mentioned assuming its wonted place. From this arch, in the north, arose almost incessant streamers of bright white light, which shot upwards to the zenith, and streaked the dark sky with their silvery lines.

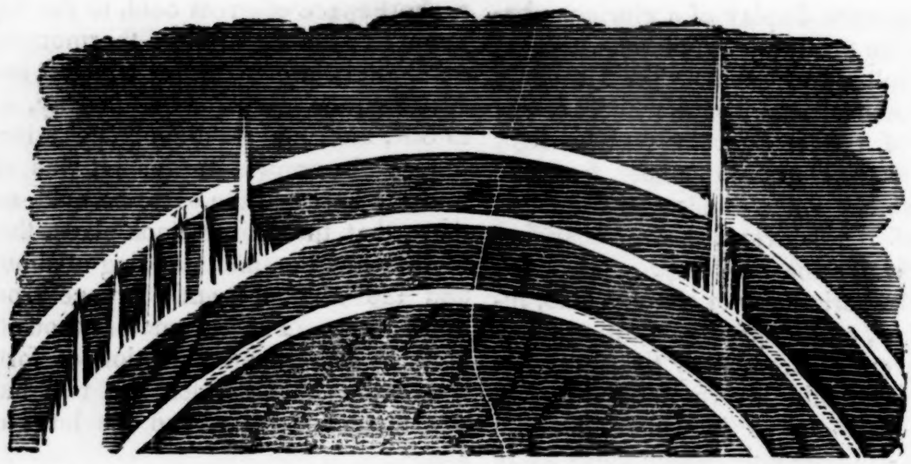
Once a mass of light suddenly opened in the zenith, and from it darted out innumerable pencils of bright rays, overspreading the dark vault of heaven with their glories, and seeming for a moment to illuminate the sky with a star which its vast space was scarcely capable of containing.

Again, rods of white light would dart forth from the northern horizon, and one single one, in particular, spanned the whole arch of heaven, touching the southern horizon over the great lake.

This play of the Aurora continued from seven till near nine, and was most brilliant and magnificent about nine, when it assumed another and not less singular attitude, of which the following is a faint attempt to delineate.

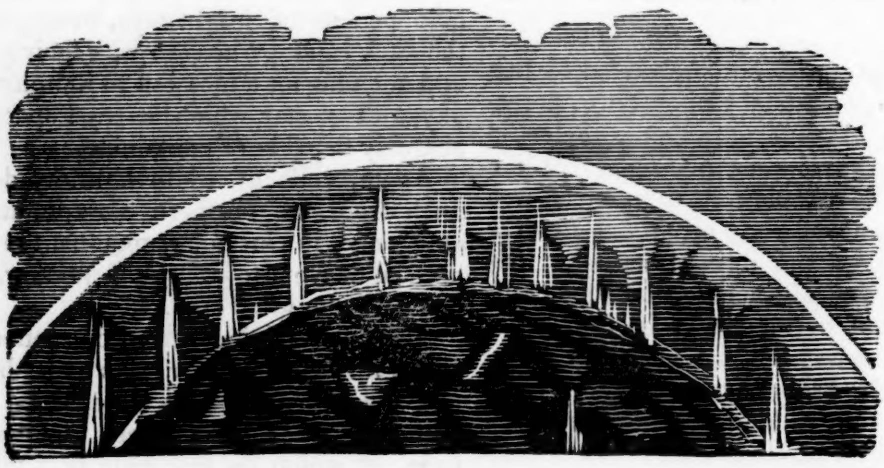
These arches are not so flat as they should be, but the space is insufficient to show them exactly. The lower one was usually the boundary of a very dark black, changing mass; between the lower arch and the second, the space was not so dark; and between the second and third, or upper arch, it was still lighter, excepting where the coruscations shot upwards out of the second arch, and there it was very dark. The second arch was incomplete.

* The barometrical observations were made at the Hospital on Point Henry, by a very accurate observer. On the 10th December, it indicated, at 9 A. M. 29.5, at 9 P. M. 29.7; on the 11th, at 9 A. M. 29.8, at 9 P. M. 29.9; on the 12th, at 9 A. M. 30.1, at 9 P. M. 30.1.



The ray shooting up on the right was brilliant in the extreme. Stars were partially visible above the third arch, but the bright ones in Ursa Major, on the left, had lost all their splendor, and the constellation could just be traced. The obscuration of the heavenly bodies reached almost to the zenith, above the centre of the arch, and was less over the extremeties.

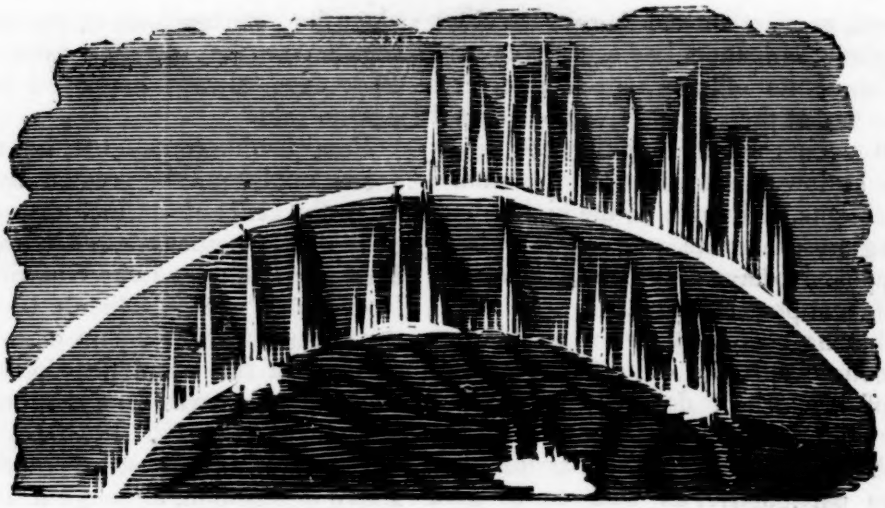
The first appearance lasted long enough for me to go into another part of the house and make a hasty sketch; on my return to the window, it was altering to the following form.



The lower arch had somewhat heightened and become darker, with here and there spots of light in it, whilst from its circumference shot out brilliant rays and pencils of light. The second arch had altogether disappeared, but the upper one held its wonted place. It must be observed, that the upper arch was always paler, and more indistinct in its outline than the others. Faint stars now appeared through the darkish vapor, between the two bands or arches of light, and the lower band was indistinct, excepting to the left of its central space, where it was vividly depicted and extremely well defined, by a sharp band of bright light, cut off, both above and below, by very black vapory masses. This second appearance lasted, also, long enough to enable me to make a hasty sketch of it.

None of the pencils or rays, which shot out of either of the changes of the Aurora, were so quick or so intensely vivid in their action or light, as those seen in the more northern regions, nor were they colored; but they were always accompanied by the black vapory shroud, which hid every thing else from view, and added greatly to the lustre of their exodus from the horizon.

Having made the foregoing sketch, I again returned to view the Aurora, which had somewhat changed its appearance.

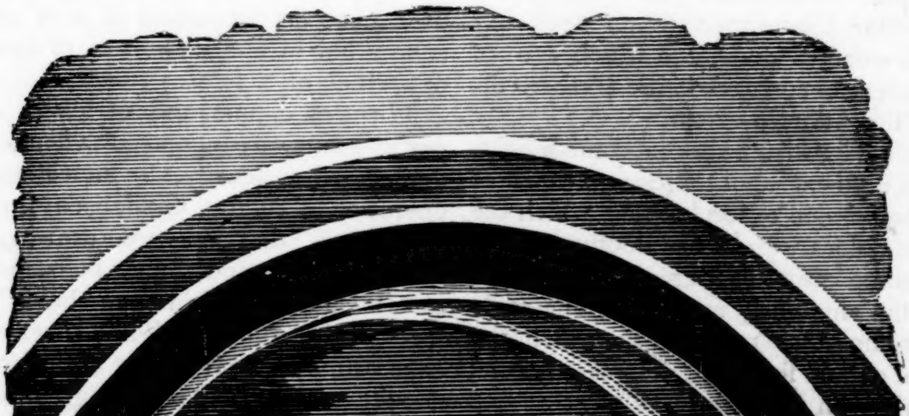


Both arcs or belts were now less distinct, the lower one almost obliterated, but still its place was well marked by the arch of vapor below, which was darker than ever. Three large spots of intense light now displayed themselves, one on the horizontal chord, and one an each side of the lower arch, whilst this lower zone shot out innumerable pencils and floods of light from its dark nucleus, the upper zone also darting forth long lines of brilliant rays; all these rays from both hands, moving in a very stately march or progression from east to west.

Towards the southern and western portions of the heavens, all was clear blue-black starlight, Orion being particularly brilliant; the north was as if overspread with a thin veil, through which the stars were barely visible.

I watched these alterations of the phenomenon until after ten; and the last I observed presented this form; after which the arches became less distinct, and eventually, with the exception of the great arch, passed away.

In this fourth change the Aurora, it will be observed, resumed its three arches, but they were no longer concentric, the third being broken on the right into a portion of a fourth. Between the second and third the darkness was the darkness of blackness, whilst the third arch was light itself; but the lower arches were not so bright, and the lower nucleus was only darkish, which was contrary to every state that it had presented, under any former observations for several years.



The constant arch of the Aurora of the Lakes has, I believe, never been noticed in any scientific publication, as is well worthy the attention of the learned. Whether it is created by a peculiar locality of the matter, of which the substance of the Aurora is

composed, or whether the Aurora itself. as the magnetic influence, has a peculiar pole from whence its effluences emanate, can scarcely be, at present, determined; but it is at all events highly singular, that in a latitude so low as 44°, the Aurora should assume forms, unknown in the higher northern regions where its powers were hitherto supposed to have developed themselves in the highest possible state.

Not having been very well when this singular scene occurred, I did not take all that notice of it which it deserved. I trust I shall be able during the winter to note the atmospheric phenomena which accompany it, more particularly, as well as to give more detailed accounts, and more perfect drawings.

II. *Solar Phenomenon.*

Immediately previous to the alteration of the weather at Kingston on Lake Ontario, after an unusual duration of severe frost, and about the middle of March, at near four o'clock in the afternoon of Sunday, I observed a singular species of halo or rainbow.

The day was mild, and there was scarcely any wind, and no rain, but the face of the sky was overclouded, and the sun appeared as it does through a slight fog.

Around the luminary, at a radial distance of perhaps twenty degrees, there was a dark halo of the usual defined character and appearance; and circling this halo in various places, a rainbow was visible. This rainbow was brightest in the eastern and western parts of the halo, where it assumed that peculiar appearance which seafaring men call weather dogs, and which are of very frequent occurrence in the northern division of the Atlantic ocean.

It was evident from the dull whitish light, that was diffused about those portions of the circumference of the halo on which the prismatic colors were not perfectly defined, that, in some situations, an observer might witness the singularly interesting spectacle of a circum-solar rainbow, in which the prismatic colors formed a complete circle, concentric with the sun.

In the course of the winter season, during changes of the weather from frost to a thaw, I have frequently observed a small portion of a vertical arch of the above description, although the sun was hardly visible. Usually these occurrences have taken place when the sun has been at the same elevation, as in the instance here described. They have always happened when there was no rain.

I am unable to say whether the appearances might not be created by reflection from the brilliant surface of such a vast body of ice, unincumbered by snow, as has been presented by Lake Ontario during the last winter, as it is difficult to account for the formation of a rainbow of so small a diameter on the usual principles, since the sun at the time was forty degrees above the horizon.

I have used the word rainbow in the above description, although it is not a correct one, as there were no appearances of rain during the presence of the phenomenon, although it is true there was a slight mist or fog.

Since writing the above, I have seen an almost complete circum-solar rainbow, which appeared at Toronto, (U. C.) July, 1834, at 7 in the morning.

Effects of Drawing, Rolling, Annealing, &c., of the Metals.

In a paper on the ductility and malleability of certain metals, and on the variations of density which they undergo by different operations, M. Baudrimont developes the following interesting facts.

At a temperature rather above a cherry red, iron wire remained three months, surrounded by charcoal, without cementation taking place. A white heat, in five minutes, gave the properties of cast iron to a square bar of malleable iron, of four-tenths of an inch on a side.

Wires of copper, and of alloys of copper and zinc, are increased in diameter, and diminished in density, by annealing. The operation of rolling condenses the metals more than that of wire drawing. The density of iron and copper is greater, if the metals are heated before being passed through the rollers. The reverse is the case with alloys of copper and zinc. The density of the metals is greatest when drawn into very fine wires.

Wires may be increased in length in two ways, by a diminution in the area of their cross section, or by increasing the distances between their particles. When wires are lengthened in the manner last

named, they return to their former length by annealing.

Hydrogen has an action on copper and silver, at high temperatures, which permanently separates their particles. On alloys of copper and zinc, and even of silver and copper, it has no such action.

Wires of different metals, which, after passing through the same hole in the wire drawing plate, have different diameters, acquire equal diameters by annealing.

The diameter of a wire increases, very slowly, by time, after passing through the wire drawing plate. Wires which have been bent, and then straightened, re-acquire a curvature.

Wires exposed to a high heat, lose a part of their tenacity. They require to be annealed in wire drawing, not to render them more tenacious, but to allow the particles to resume the positions from which they may again be displaced. The loss of tenacity is common to copper, iron, platinum, and the alloys of copper and zinc.

Brass wire approaches to iron in strength, while copper is inferior to it. Brass may be used instead of iron, where the latter would oxidate too rapidly.

The iron wires are given at strengths from 79,000 lbs. to the square inch to 127,600 lbs. The brass wires, from 78 to 87,000 lbs. to square inch. Copper, from 38 to 44,000 lbs. The diameters of the least and greatest wires were, iron, .014 inch, and .205 inch; brass, .070 and .267 inch; copper, .019 and .285 inch.

The finer wires bear greater weights, in proportion to their areas, than the coarser ones, because the particles of the former are compacted through the whole cross section, while those of the latter, for a certain depth only, are thus forced together.—[Ann. de Chim. et de Phys.]

A short Remark or two on what is commonly called Dry Rot, by Chas. Waterton, Esq.

Dry rot is a misnomer. This disease in timber ought to be designated a decomposition of wood by its own internal juices, which have become vitiated for want of a free circulation of air.

If you rear a piece of timber, newly cut down, in an upright position in the open air, it will last for ages. Put another piece of the same tree into a ship, or into a house, where there is no access to the fresh air, and ere long it will be decomposed.

But should you have painted the piece of wood which you placed in an upright position, it will not last long; because, the paint having stopped up its pores the incarcerated juices have become vitiated, and have caused the wood to rot. Nine times in ten, wood is painted too soon. The upright unpainted posts, in the houses of our ancestors, though exposed to the heats of of summer, and the blasts of winter, have lasted for centuries; because the pores o. the wood were not closed by any external application of tar or paint; and thus the juices had an opportunity of drying up gradually.

In 1827, on making some alterations in a passage, I put down and painted a new plinth, made of the best, and apparently, well-seasoned foreign deal. The stone wall was faced with wood and laths; and the plaster was so well worked to the plinth, that it might be said to have been air-tight. In about four months, a yellow fungus was perceived to ooze out between the bottom of the plinth and the flags; and on taking up the plinth, both it and the laths, and the ends of the upright pieces of wood to which the laths had been nailed, were found in as complete a state of decomposition as though they had been buried in a hot-bed. Part of these materials exhibited the appearance of what is usually called dry-rot; and part was still moist, with fungus on it, sending forth a very disagreeable odour. A new plinth was immediately put down; and holes, 1½ inches in diameter, at every yard, were bored through it. This admitted a free circulation of air; and to this day the wood is as sound and good as the day on which it was first put down. The same year I reared up, in the end of a neglected and notoriously damp barn, a lot of newly felled larch poles; and I placed another lot of larch poles against the wall on the outside of the same barn. These are now good and well seasoned: those within became tainted the first year, with what is called dry rot, and were used for fire-wood.

If, then, you admit a free circulation of air to the timber which is used in a house (no difficult matter) and abstain from painting that timber till it be perfectly seasoned,

you will never suffer from what is called dry rot. And if the naval architect, by means of air-holes in the gunwale of a vessel (which might might be closed in bad weather), could admit a free circulation of air to the timbers; and if, he could, also, abstain, from painting, or doing with turpentine, &c., the outer parts of the vessel, till the wood had become sufficiently seasoned, he would not have to complain of dry rot. I am of opinion, that if a vessel were to make three or four voyages before it is painted, or done with turpentine, &c., its outer wood would suffer much less from the influence of the weather, than it usually suffers from its own internal juices, which cannot get vent, on account of artificial applications to the pores. But still the timber would be subject to the depredation of the insect. To prevent this effectually, Mr. Kayan's process must absolutely be adopted; and it must also be adopted to secure wood from what is called the dry rot, in places where a free circulation of air cannot be introduced. I consider Mr. Kyan's process perfectly unexceptionable.—The long arrows which the Indians use in Guiana are very subject to be eaten by the worm. In 1812, I applied the solution of corrosive sublimate to a large quantity of these arrows. At this hour they are perfectly sound, and show no appearance that the worm has ever tried to feed upon them.

I have penned down these transient remarks by way of preface to others, which I may possibly write, at some future time, on decay in living trees.—[Loudon's Architect. Mag.]

New Spirit Lamp.—A new and convenient spirit lamp, with an eolipyle having a vertical jet, is described by M. Pelletan, the invention of M. Breuzin, of Paris.—The entire apparatus is placed on a neat tripod stand, arranged for holding the vessel to be heated. The wick of the lamp is hollow, and is raised or depressed by a screw and rack. Above the lamp is an eolipyle of cylindrical shape, through the middle of which the flame of the lamp passes. The vessel to be heated being placed above the eolipyle, retains the full effect of the flame of the lamp. The jet pipe from the eolipyle passes downwards, and by a bend is introduced into the axis of the cylindrical wick of the lamp. The alcohol flame is thus entirely vertical, and the apparatus is much more convenient than the common eolipyle where the jet is horizontal. By using vessels properly arranged to economise heat, a pint of water may be boiled in five minutes, and at a cost of less than half a cent (at Paris). In a common coffee biggin, the same quantity of water may be boiled for about a cent.—[Jour. Connaiss. Us. et Prat.]

Application of Tannate of Gelatin to taking Casts from Medals, &c.—This substance is obtained by adding a decoction of gall nuts, sumac, oak bark, or other substance containing tannin, to a solution of glue or isinglass, in water. It is fibrous and nearly insoluble. When exposed to the air in thin layers, it hardens. When moist, it is elastic.

The substance which was found to give the best mixture for casts, was finely pulverized slate. Silica, emery, &c. give pastes which harden, and may be used for razor straps.

In making casts of the mixture of tannate of gelatin and pulverized slate, it must be left for a certain time in the mould, in order to preserve the impression. If, however, it is allowed to remain there too long, it adheres strongly. The only difficulty in the application is to ascertain the precise time required for due hardening.

This substance may replace bronze in ornaments, papier mache, card work, &c. —[Ibid.]

Analysis of two varieties of Bronze.—These specimens were analyzed by M. Berthier. The first was intended for the manufacture of cannon, but proved of bad quality; its composition was ascertained to avoid the same proportions in other mixtures. It consisted in 100 parts, of copper 83.8, tin 15.7, lead 0.5.

The bronze used at Paris for the striking parts of clocks, was found to be composed in 100 parts, of 71 to 72 of copper, 26.56 to 27 of tin, 1.44 to 2 of iron.—[Ann. des Mines, vol. VII.]

Sheathing of Ships with Bronze.—The sheathing of this metal has been found by experiment, to lose but half the weight, in a given time, which copper would have lost. The composition used for making sheet bronze is 91 of copper and 9 of tin. —[Ibid.]

Durability of Acacia Wood.—It was found that in the mining galleries at Carmaux, (France) the oak timber used to support the sides and top of the galleries, decayed very rapidly, being effected by the dry rot. A comparative experiment was made with acacia wood, from which it resulted that the latter wood is much more durable than the former, when exposed in such situation. Oak timber decayed in three months, while the acacia was unacted upon, except at the sap-wood surface, four years.

The lateral strength of this wood is about equal to that of Norway pine.—[Ann. des Mines, vol. VII.]

The following article contains hints useful to instrument makers and tuners. We have always been of the opinion that the practice of our predecessors in such matters has not been properly treated before adoption. The manufacture of musical instruments is increasing daily, in our country it has always been a favorite subject to us, and we desire to hear and see more of improvements in that branch.

ON TUNING—NEW MATHEMATICAL DIVISION OF THE SCALE.

Sir,—The following is a mathematical division of the scale, assuming the bass C as 30 inches:—

C	. . .	$30.$
C *sharp*	.	$28\frac{5508}{59049}.$
D	. . .	$26\frac{39366}{59049}.$
D *sharp*	.	$24\frac{51008}{59049}.$
E	. . .	$23\frac{41553}{59049}.$
F	. . .	$22\frac{11642}{59049}.$
F *sharp*	.	$21\frac{4131}{59049}.$
G	. . .	$20.$
G *sharp*	.	$18\frac{43038}{59049}.$
A	. . .	$17\ \frac{27}{49}.$
A *sharp*	.	$16\frac{38256}{59049}.$
B	. . .	$15\frac{15975}{59049}.$
C	. . .	15

It is obtained thus:—

$\frac{2}{3}$ of 30	$= 20$	G above.
$\frac{2}{3}$—20	$= 13\frac{1}{3}$	$\times$ 2 D.
$\frac{2}{3}$—$13\frac{1}{3}$	$= 8\frac{8}{9}$	$\times$ 2 A.
$\frac{2}{3}$— $8\frac{8}{9}$	$= 5\frac{25}{27}$	$\times$ 4 E.
$\frac{2}{3}$— $5\frac{25}{27}$	$= 3\frac{77}{81}$	$\times$ 4 B.
$\frac{2}{3}$— $3\frac{77}{81}$	$= 2\frac{154}{243}$	$\times$ 8 F *sharp.*
$\frac{2}{3}$— $2\frac{154}{243}$	$= 1\frac{551}{729}$	$\times$ 16C *sharp.*
$\frac{2}{3}$— $1\frac{551}{729}$	$= 1\frac{373}{2187}$	$\times$ 16G *sharp.*
$\frac{2}{3}$— $1\frac{373}{2187}$	$= \frac{5120}{6561}$	$\times$ 32D *sharp.*
$\frac{2}{3}$— $\frac{5120}{6561}$	$= \frac{10240}{19683}$	$\times$ 32A *sharp.*
$\frac{2}{3}$— $\frac{10240}{19683}$	$= \frac{20480}{59049}$	$\times$ 64F.

These multiplyers are not arbitrary numbers, but as the second stage brings us beyond the first octave, we must double it to bring it within the octave; and as the fourth stage brings us beyond the second octave, it must be twice doubled (or quadrupled), and so on of the rest.

A piano forte tuned according to this scale would, I think, have a very pleasing effect: but, independent of the impossibility of tuning to that exactness, piano forte makers, instead of doubling the length of string to produce the sound of the octave below, *must necessarily* use a thicker wire, or we should have piano fortes as large as houses.

The following is Earl Stanhope's scale:—

C—C, perfect octave.
C—G, perfect fifth.
C—E, perfect third.
E—B, perfect fifth.
C—F, perfect fifth.
F—B *flat*, perfect fifth.
E—A *flat*.bi-equal third.*
A *flat*—C, bi-equal third.
A *flat*—E *flat*, perfect fifth.
A *flat*—D *flat*, perfect fifth.
G *flat*—G *flat*, perfect fifth.
D—D, D—A, A—E, three tri-equal fifths.†

These tri-equal fifths, though flat, are not of such a degree of flatness as to be offensive to the ear; differing from a perfect fifth only 829,885 parts in 300,000,000, or $\frac{829885}{3000000000}$. If this interval G—E, as in Kimberger's method, be divided into one perfect fifth, and two equally flat fifths—such, for instance, as the perfect fifths G—D, and the equally flat fifths D—A and A—E; then each of these two last fifths, by becoming too flat, is offensive to the ear. And if that same interval be divided into two perfect fifths, and one flat fifth, then this flat fiifth so produced is still more offensive.

In tuning each key throughout the whole instrument, too much attention cannot be paid to the beatings, as that is by far the most accurate way of tuning by the ear. For, whenever a third, fourth, fifth, sixth, or octave is quite perfect, there is no beating

* A bi-equal third is thus obtained;—from one perfect octave deduct one perfect third, and divide the remainder into two equally sharp thirds.

† A tri-equal fifth is thus obtained:—divide the interval included by a perfect fifth from the key-note, and the second perfect octave above the perfect third from the same key-note, into three equally flat fifths which are tri-equal fifths.

to be heard. But, on the contrary, when any of them are in any degree imperfect, though not distant from perfection, a beating is always audible. A very slow beating proves that the distance from perfection is not great; but as the beating becomes quicker, the distance from perfection becomes more considerable, and, from the equality of the beatings, *equal deviations* may in like manner be correctly ascertained.

Some tuners in order to assist the fifths, have proposed to tune the octaves a little imperfect. The objection to this are obvious, for if we *sharpen* the octaves to assist the fifths, it injures the thirds; and if we *flatten* the octaves to assist the thirds, it injures the fifths. Such is the construction of the human ear, that we can bear a much greater deviation from perfection in the fifths than we can in the octaves, and a still greater deviation in thirds than either the fifths or octaves. Again, however small the deviation may be in a single octave, it becomes very sensible in two or three, and most offensive in six or seven.

We have been in the habit of considering the Wolf as an inherent imperfection in every instrument that has exactly twelve fixed keys in each septave; whereas so far from being an imperfection, it is precisely the proper distribution of it that produces that charming variety of character between the different keys, which is so essentially requisite in a well tuned instrument.

April 8, 1836. CORIO.

MACHINE FOR REGISTERING THE VARIATIONS OF THE TIDE AND WIND.—The general principle of the machine is such, that a circular dial being fixed to the axle of a clock, revolves with a uniform motion once in twenty-four hours; a pencil is also moved vertically up and down by the rise and fall of the tide; which combined motions of the dial and pencil trace a curve upon the face of the dial, whereby the height of the tide, at any particular period of time, may be ascertained; also the time of high and low water, and the variable rate of ascent and descent.

The direction of the wind is indicated by a circular dial, fixed horizontally to the vertical axis of a wind-vane; and, by means of the clock, a pencil is made to move uniformly, at a given rate, from the centre of the dial, towards the circumference, so that, if the wind remain stationary upon any point of the compass, the mark traced by the pencil will be a straight line, radiating from the centre of the dial; but if the wind be changing, the dial will revolve, and the combined motions of the dial and pencil will trace out a curve, by which the direction of the wind, at any particular period of time, will be indicated.—*Jameson's Journal.*

EXPANSION OF LIQUIFIED GASES, &c.—The very remarkable fact of the expansion of liquified carbonic acid, lately observed by the French academicians, has been fully verified by Mr. Kemp, lecturer on chemistry, who finds that the expansion is not peculiar to this liquified gas, but belongs to all other gases in the liquid state. At a meeting of the society of arts, Mr. Kemp exhibited a specimen of the liquified sulphurous acid gas, hermetically sealed in a glass tube, and separated from the materials from which it had been generated. This specimen of the liquified gas occupied eight inches of a tube, five eighths of an inch in internal diameter, and when cooled from the temperature of 60° down to 14° of Fahr., or the point at which it becomes liquid under the ordinary pressure of the atmosphere, it contracted one inch; but when heated an equal number of degrees above 60°, viz. 46°, it expanded through a greater distance than it had before contracted, by the abstraction of an equal amount of caloric, showing that the expansion went on at higher temperatures in a slightly increasing ratio, so that the expansion between its liquifying point, viz. 14° and 212°, the boiling point of water, is nearly one-third of its whole volume, the preseure against the expansion being at 212°, about twenty-five atmospheres. That this property does not belong to the liquified gases exclusively, but resides equally in all other fluids, when raised above their boiling points, is shown by the following experiment; thus, ether, when raised from the temperature of 60° to 95° of Fahr., or its boiling point, undergoes an inconsiderable expansion compared with the expansion produced by an equal increase of temperature above its boiling point, when it may be said to be in the same condition with the liquified gases, in regard to pressure, and suffers nearly an equal expansion, by an equally increasing temperature with the liquified gases.—*Jameson's Jour.*

PAMBOUR ON LOCOMOTION.

(Concluded from page 64.)

If we sometimes find calculations of the power of locomotive engines, or any other sort of steam engines, in which there appears what is termed *lost power;* that is to say, calculations according to which it would appear that these engines produce in practice only one-third or even a quarter of what

is termed their *theoretical power;* and if that difference between practice and theory be at present so generally established, that it is taken as a rule to say that *practical horses* are only the third part of *theoretical horses*, the reason is, simply, that this supposed theoretical power is wrongly calculated. All the different circumstances of which we have spoken above have not been duly taken into account. Before all calculations, the atmospheric pressure has been deducted; the resistance of the engine, or its increase in proportion to the load, has been omitted; and, above all, the pressure on the piston has been calculated as equal to the pressure in the boiler, though we have seen how different they are from each other. With so many causes of error, it is not surprising that results should have been obtained, which are contradicted by experience; or, in other words, that one should construct very good engines without being able to calculate their power or effects. But if we take into account all the resistances really conquered, and the velocity of their points of application; if we take the pressure in the cylinder as it really is, instead of considering a power as applied when it is not; in that case we shall obtain a most remarkable result, applicable, moreover, to all sorts of steam-engines, viz. that all the power applied is to be traced in the effect produced, and that there is not one single pound of which the use may not be pointed out.

CHAPTER VI.

OF SOME ACCESSORY DISPOSITIONS AND THEIR EFFECT.

ARTICLE I.

OF THE REGULATOR.

§ 1. *Effect of the opening of the Regulator.*

Three accessory parts or dispositions are still to be considered, which have a considerable influence on the effect of locomotive engines; these are the *regulator*, the *blast-pipe*, and the *lead* of the slide, which we are going to describe successively.

We have observed that the pipe, which leads from the boiler to the cylinders, may be either completely or partially shut by means of a cock or regulator. When the regulator is quite open, the steam enters into the cylinder as freely as the area of the pipe through which it must necessarily pass. Then the speed is as great as the generation of steam permits. If, by means of the regulator, we diminish a little the entrance of the pipe, the steam may take at first a greater velocity, which surplus of velocity may allow, as before, the egress of all the steam generated. In that case the effect will remain the same as in the former one, and as long as the width of the passage is not out of proportion with the generation of the steam, there will be no diminution in the effect of the engine.

If, however, we continue to shut the passage, we shall necessarily arrive at last at a point where it will be so narrow, that it will form a considerable obstacle to the admission of the steam. From that moment, only a portion of the steam generated in the boiler will be able to get into the cylinders, and consequently the effect produced will be diminished in the same proportion.

Having called *effective* evaporating power the mass of steam the engine is able to introduce into the cylinders in a unit of time, we clearly see that the motion imparted to the regulator causes a diminution in the effective evaporating power of the engine; and then the formula, such as we have given it above, shows why the effect is diminished.

In fact, we find in practice that the same train will be drawn by the same engine at different speeds, according to the size of the aperture of the regulator. This is the method invariably used on the Liverpool Railway to prevent the trains, when they are too light, from being carried along with greater rapidity than the preservation of the engines, the carriages, and the Railway can allow. This manner of regulating the speed is so far advantageous, that, if on the road there occur either a slight inclination or any obstacle whatever, one may, by opening the regulator, and animating at the same time the fire, restore to the engine its full power, and enable it to pass over the obstacle without diminishing its speed.

The size of the aperture of the regulator is, therefore, to be taken into account, when the question is to ascertain the effect of the engine. That is the reason why we have noted it in the experiments related above. We should have preferred the handle of the

regulator to have turned on a graduated circle, in order to be able to measure exactly the degree of opening, and compare it with the corresponding effects; but, with the present construction of the engines, it is only by approximation that we can judge of the size of the aperture.

§ 2. *Of the Steam Pipes.*

Carrying still further the same principle, on the free motion of the steam, we see that between two engines, perfectly similar in other respects, there must be an advantage in favor of that one in which the steam-pipes have a more considerable area. It is, however, clear, that as soon as we have attained a diameter sufficient for the passage of all the steam that a boiler is able to generate, at the greatest speed with which the engine is required to go, nothing further is to be gained by augmenting still more that diameter. It is for the same reason that we have seen, a little while ago, that that passage may be reduced to a certain degree without loss of effect, which is owing to the opening having been originally greater than was necessary.

Experience has fixed the diameter that must be given to the steam-pipes, and would quickly give notice if it were not observed; for if it should happen, for instance, that an engine, running with all its speed, should still emit steam through its safety-valve, that would be a proof that the area of the passage is too small for the quantity of steam the boiler is able to generate.

§ 3. *Table of the Dimensions of the Steam-Pipes in some of the Engines of the Liverpool and Manchester Railway.*

There exists, then a suitable diameter, harmonizing with the evaporating power of the engine, or with the dimensions of the boiler. It is for that reason we give here the diameter of the steam-pipes, in the engines we have submitted to experiment, and in some others, the proportions of which were given at the beginning of this work. The steam-pipes considered here are those which lead separately from the boiler to each slide-box. Those which lead afterwards from that box to the interior of the cylinders have a corresponding area, although of a different form. Their dimensions will be, for instance, 1 inch broad to 7 inches long, which will present the same surface, as a tube of 3 inches diameter.

DIAMETER OF THE STEAM-PIPES IN SOME OF THE ENGINES OF THE LIVERPOOL AND MANCHESTER RAILWAY.

Name of the Engine and Number of its construction.	Diameter of the Cylinder.	Stroke of the Piston.	Heating-surface: Exposed to the action of Radiating Caloric.	Heating-surface: Exposed to the action of Communicative Heat.	Inside Diameter of the Steam-Pipes.	Remarks.
	inches.	inches.	sq. ft.	sq. ft.	inches.	
SAMSON, No. 13	14	16	40.20	416.90	3.25	This engine is now under repair, and the steam-pipes will be 4 inches in diameter.
GOLIATH, No. 15	14	16	40.31	407.00	3.25	
ATLAS, No. 23	12	16	57.06	217.88	3.25	
VULCAN, No. 19	11	16	34.45	307.38	3.50	
FURY, No. 21	11	16	32.87	307.38	3.50	
VESTA, No. 24	11	16	46.00	256.08	3.25	
LEEDS, No. 30	11	16	34.57	307.38	3.50	
FIREFLY, No. 31	11	18	43.91	362.60	3.00	

ARTICLE II.

OF THE BLAST-PIPE.

In describing the engine, we have said that the steam, after having produced its effect in the cylinder, is let into the chimney. It enters it in a jet, through a pipe turned upwards, and terminated by a narrow orifice, wihich is placed in the middle of the chimney-flue. The disposition of that pipe, called the *blast-pipe*, is represented in fig. 5.

The steam, at each jet, clearing before it the column of air that filled the passage of the chimney, leaves a vacuum behind it. This vacuum is immediately filled up with a mass of exterior air that rushes through the fire-place to occupy the space where the vacuum has been made. In consequence, after each aspiration thus produced, the fuel in the fire-place grows white with the intensity of the heat.

This effect is similar to that of a pair of bellows that would constantly animate the fire, and the artificial blast created by that means in the fire-place is so necessary to the work of the engine, that if the pipe happens to be broken, burnt, or leaky, the engine becomes almost useless; which shows that the ordinary draft of the chimney is very small in comparison.

It is easy to conceive, that the narrower the orifice, the more violent will be the current that escapes through it, and the greater its effect in animating the fire. The result is, consequently, a greater generation of steam in the same space of time, or an increase of power in the engine. This is, therefore, an important point to note when the effect produced by an engine is to be described; for if the diameter of the blast-pipe is changed, the evaporating power of the boiler will be changed also.

In the engines that served for the above experiments, the diameter of the orifice of the blast-pipe was $2\frac{1}{4}$ to $2\frac{1}{2}$ in., which is their usual dimension. The LEEDS engine must, however, be excepted from the general rule, the diameter of her blast-pipe being only $2\frac{3}{16}$ in. As for the ATLAS engine, her blast-pipe was $2\frac{15}{16}$ in. in diameter in all the experiments, except on the 4th of August, when it had been carried to $3\frac{1}{16}$ in., in order to observe what reduction would result from that circumstance on the effect of the engine. Comparing that experiment with the others made with the same engine, the diminution of speed seems to have been nearly in the proportion of 15 to 17. The effect produced would thus be in the inverse proportion of the square of the diameter of the pipe, or of the area of the orifice; that is to say, in a direct ratio to the velocity with which the steam escapes into the chimney.

To those dimensions, therefore, as to one of the elements of production, must be referred the evaporation effected by the engines.

The generally adopted dimensions of $2\frac{1}{4}$ to $2\frac{1}{2}$ in. diameter for the orifice of the blast-pipe is the result of experience. It has been endeavored to diminish the aperture as much as possible, without putting a material obstacle to the escaping of the steam; that is to say, that the tube has been narrowed as long as the effect was seen to augment, and that a stop was put to the trial as soon as it was found that there was no more gain of power.

With an orifice $2\frac{1}{2}$ in. in diameter, or 5 sq. in. area, and cylinders of 11 in. diameter, or 190 sq. in. total area; that is to say, with an orifice which is only $\frac{1}{38}$ of the area of the cylinders, we see, that in order that all the steam may get out by that passage, its speed in passing through the orifice must be 38 times as great as it was in the cylinder.

The velocity of the jet formed in the chimney will then be, for the dimension we consider, equal to 38 times the velocity of the piston, or in other words, equal to $6\frac{1}{2}$ times the speed of the engine, this latter speed being nearly six times as great as that of the piston.

Thus the power of this additional means will be greater in proportion as the velocity of the engine itself will be more considerable. If, for instance, the engine travels 30 miles an hour, the velocity of the jet will be 195 miles an hour, or 286 feet per second; and as that velocity cannot be produced merely by the tendency of the steam to escape into the atmosphere, a part of the power of the engine itself must necessarily, in those great speeds, be spent in expulsing the steam; that is to say, in blowing the fire in the fire-place. Consequently, the increase of effect being produced by a sacrifice of power, a point will naturally come where the profit is balanced by the expense required to obtain it, and there all advantage will cease. This explains the point determined by practice as the limit of the narrowing of the orifice.

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ARTICLE III.

OF THE LEAD OF THE SLIDE.

§ 1. *Nature and Effects of the Lead.*

The third disposition which we have to discuss, is the *lead* of the slide.

In describing the different parts of the engine, we said that it is the slide that opens and shuts successively the passages above and below the piston, so as to apply the effort of the steam alternately on one side and on the other. If the engine were regulated, as it appears natural that it should be, the slide would keep the passage open to the steam until the piston had reached the bottom of the cylinder. At that instant the change would take place. The first passage would be shut, and the opposite passage opened. Then the motion of the slide would accompany exactly that of the piston. Their alternation would be strictly simultaneous.

But this is not the case; it has been found by experience, that the engine is capable of acquiring a greater speed when the motion of the slide precedes that of the piston; that is to say, when it opens the passages to the steam a little before the necessary moment. When the engine is regulated in that manner, at the moment the piston is going to begin a new stroke, the passages, instead of beginning to open, have already a certain degree of aperture. This premature degree of aperture is called the *lead of the slide*, because it indicates in how far the motion of the slide precedes that of the piston. In fact, we can conceive, that if the return of the slide is, for instance, a quarter of an inch in advance on that of the piston, the passages for the steam will have a quarter of an inch aperture when the piston touches the bottom of the cylinder.

The effect of that disposition, first on the speed and then on the load, are the two points we intend to examine here.

The common way of explaining the increase of speed the engine acquires when it has a little lead, is by saying, that by that means the steam is ready to act on the piston at the moment the piston begins its stroke. But it is not difficult to see, that if the steam really acts quicker at the beginning of the stroke, it is also sooner interrupted at the end of the stroke. The effect would thus only be, to add on one side what is substracted on the other. That explanation is, therefore, by no means satisfactory.

But the manner in which the calculation of the speed of the engines has been established here-above, gives us immediately the real explanation of the fact.

If the change in the passages of the steam, instead of occurring exactly at the end of the stroke of the piston, takes place, according to our supposition, at the moment the piston is still an inch from the bottom, from that instant no more steam enters the cylinder. In fact, on one side the passage is shut; it is true that it is open on the other, but the piston, which must necessarily finish its stroke, keeps the steam pressed back in the passages, from whence it cannot get out until the piston begins to take its retrograde direction. Thus, in regard to the quantity of steam admitted in the cylinders at each stroke of the piston, the length of that stroke is in reality diminished by an inch. We have seen that, to know the velocity of the piston, we must divide the mass of steam generated in the boiler by the area of the cylinders (Chap. V. Art. V. § 1,) and that the quotient will be the speed with which that volume of steam must necessarily pass through the cylinders, or the velocity of the piston. That will really give the velocity wanted, if the steam issues without any interruption; but if, as it is here the case, there occurs at each stroke a suspension in the issuing of the steam, it is evident that, for the same quantity of steam to go through the cylinders, a greater velocity of motion will be required. It is the generation of steam in the boiler that regulates and limits the speed; if, therefore, we suppose that the generation supplied m cylinders full of steam in a minute, when the total length l of the cylinder got filled with steam, that the length $l - \epsilon$ only gets filled, the same quantity of steam will fill per minute a number of cylinders expressed by $m \times \frac{l}{l - \epsilon}$. Then the speed of the piston will be augmented in the inverse proportion of the length of the cylinders that get full of steam.

We see why the lead is favorable to the speed. But if there be profit in that respect, there is loss in regard to the load that the engine is able to draw.

Suppose the line E D (fig. 25) represents the stroke of the piston, and that the stroke takes place in the direction of the arrow. The passage being shut on one side of the piston a little before it is opened on the other side, as we shall see below, let A be the point where the piston is, when the arrival of the steam is intercepted on the

side E, and let C be the point where it is when the slide begins to admit the steam on the opposite side, that is to say, on the side D.

It is clear, that at the instant the piston reaches the point A, the moving power that produced the motion is suppressed. Moreover, when the piston, continuing its stroke by virtue of its acquired velocity, reaches the point C, not only has it ceased receiving any impulsion in the direction of the motion, but it suffers even an opposition from the steam admitted in a contrary direction. The piston, however, cannot stop. It must finish its stroke. It must, therefore, repulse that fresh steam that opposes it. As it necessarily spends in the conflict a force equal to that which the steam would have communicated to it, the consequence is, that during the space C D there is not only suspension of the action of the moving force, but even introduction of that moving force in a contrary direction, and in the same proportion destruction of the force previously acquired.

We see, therefore, that the effect of the moving power, in regard to the motion, is only produced on the length of the stroke, first diminished of A D, and then of C D; so that, if those two distances are represented by ϵ and a, the effect we are really entitled to expect from the engine is only in proportion of a stroke $l - \epsilon - a$.

Now we have seen (Chap. V. Art. V. § 4) that the limit of load an engine can draw, is determined by calculating the pressure on the piston as equal to the pressure in the boiler, or expressed by —

$$M = \frac{(P - \rho)\, d^2 l}{(\delta + n)\, D} - \frac{F}{\delta + n},$$

expression in which l represents the stroke of the piston. It is clear, that the limit of load will be smaller in proportion as the stroke is diminished, and that setting aside the friction of the engine, or the term $\frac{F}{\delta + n}$, the load will be reduced in proportion to the length of the stroke.

Thus we see what are the effects of the *lead*.

The *maximum* load the engine is able to draw becomes less considerable, and its diminution is very nearly in the proportion of $\frac{l - a - \epsilon}{l}$.

On the other hand, for all loads that remain below that limit, the engine increases its speed in the proportion of $\frac{l}{l - \epsilon}$.

The surplus of effect produced in the latter case is by no means surprising. It is the natural effect of the diminution of the stroke, which enables the same mass of steam generated in the boiler to supply a greater number of cylinders in one case than in the other; and the general formula of the velocity for a given load shows it at first sight. That formula is (Chap. V. Art. V. § 1.)

$$V = \frac{m\, P\, S\, D}{(F + \delta M + n M)\, D + \rho\, d^2 l}.$$

The quantity l, which represents the stroke of the piston, only enters in the denominator. Thus, the shorter the stroke, the greater will be the velocity of the motion with the same load.

A similar effect may, besides, have been already observed in the engines. We mean the effect which results from the difference in the diameter of the cylinder. Between two engines, the cylinders of which have 12 and 11 inches diameter, all things being equal besides, the first will be able to draw a more considerable load; but with equal loads inferior to those limits, the 11-inch engine will have the greatest speed. These results are shown by the above-stated formula, and can be explained in the same manner as the effects of the lead.

§ 2. *Calculation of the Effects of the Lead.*

This is sufficient when we only wish to explain the causes of observed effects. But if we want to calculate *a priori*, and know exactly the effects of a given lead, it is necessary to ascertain the precise measure of the distances a and ϵ. That is to say, that we must determine the situation of the piston corresponding with that of the slide, at the moment that it intercepts or opens the passages.

To be able to determine the comparative situations of the slide and the piston, four circumstances already explained in the description of the engine (§ 6, 7, 8,) and which form the connexion of motion between those two parts of the mechanism, must be clearly kept in mind. (See fig. 9 and 10.)

The slide moves backwards and forwards on the three apertures of the cylinder. It goes alternately from one of its

extreme positions to the other without stopping.

This motion is produced by the revolution of the radius of the eccentric round the axis of the axle tree, which makes the effect of a common crank. But as the communication between the eccentric and the slide takes place by means of a cross-head, the slide is pushed forward when the eccentric is behind, and *vice versa.*

The radius of the eccentric stands at right angles with the crank; the consequence is, that when the crank is horizontal, the eccentric is, on the contrary, vertical, and consequently the slide is in its middle position. *Vice versa*, when the crank is vertical, the eccentric is horizontal, and the slide in its extreme position.

Finally, the piston is exactly at the end of its stroke when the crank is horizontal. Thus, it results from the preceding article that the middle position of the slide corresponds with the end of the stroke of the piston. These different effects are represented in fig. 9 and 10.

From these coincidences we see that, when the slide is in its middle position (fig. 10), the eccentric is vertical, the crank horizontal, and the piston at the end of its stroke.

When the slide is in one of its extreme positions (fig. 9) the eccentric is horizontal, the crank vertical, and the piston in the middle of the cylinder.

We see, moreover, that if the slide had no lead at all, that is to say, if the eccentric were to stand rigorously at right angles with the crank, the middle position of the slide would correspond exactly with the end of the stroke of the piston. If it deviates a little from the perpendicular, that is to say, if the slide reaches its middle position a little before the piston gets to the bottom of the cylinder, the difference will exactly be the lead we are considering.

This being granted, let us take the slide when it is in its middle position, and consequently, when the eccentric is exactly in the vertical. At that moment all is shut, as we see represented in fig. 10 and 26. But the dimensions of the slides being such that on all the openings there exists a small lap, which is generally $\frac{1}{8}$ of an inch, we see the passages were already shut an instant before this, viz. $\frac{1}{8}$ of an inch before the slide had reached this position. Thus the direction of its motion being marked by the arrow, when the slide was in the position *a* (fig. 26) all the passages began to be shut, and the steam was consequently intercepted. This is then the point at which the action of the lead begins, or which corresponds with the point A of the stroke of the piston in fig. 25.

While the slide passes from the position *a* to the position *b*, and afterwards to the position *c*, every thing remains in the same state; but once arrived at the point *c*, the passage on the right side begins to open and admit the steam on the opposite side of the piston. This is then the point corresponding with the one we have designated by C in the motion of the piston.

After having passed that point *c*, the slide continues to open more and more a passage to the steam. If the lead is $\frac{5}{8}$ of an inch for instance; that is to say, if the slide opens the passage to an extent of $\frac{5}{8}$ of an inch, at the instant the piston finishes its stroke, then in measuring from the point *c* a distance of $\frac{5}{8}$ of an inch, we shall find the point *d* where the slide will be the moment the piston is at the bottom of the cylinder. This point will consequently correspond with the one designated by D in fig. 25; that is to say, it will correspond with the end of the stroke of the piston.

This correlativeness once established, we have to determine the unknown distances AD and CD, taken on the stroke of the piston, according to the distances *ac cd*, taken on the range of the slide. These last are in fact given, the second being the lead, and the first the same lead augmented by twice the lap *ab*.

Now, if we suppose the motion of the slide backwards and forwards to be 3 in., the eccentric must produce that motion, and consequently the interval between its centre and the centre of the axle must be $1\frac{1}{2}$ in. The centre of the eccentric describes consequently round the axle a circle, the diameter of which is 3 in., while the crank of the axle describes a circle, the diameter of which is 16 in., which we suppose to be the length of the stroke.

If, therefore, we take the point *b* (fig. 27) for the centre of the axis, and if round that point we describe a circle, the radius of which be $1\frac{1}{2}$ in., that circle will be the one described by the eccentric; and its diameter will be the space run over by the slide.

If round that point we describe another circle with a radius of 8 in., it will be the circle described by the crank; and its diameter will be the stroke of the piston.

These points acknowledged, since the middle situation of the slide corresponds with the moment the eccentric is vertical, we see that that position of the slide is here the point b. As, besides, we have seen that in consequence of the slide lapping over the apertures, the steam is intercepted an instant before, if we take before the point b a space equal to the lap, we shall have the point a where the effect of the lead begins. In the same way, if we take beyond the point b another space, also equal to the lap, we shall have the point c where the passages open again. And, finally, at a distance from the point c equal to the lead, we shall have the point d, which corresponds with the end of the stroke of the piston.

Raising from these points perpendicular lines towards the circumference described by the eccentric, the points a', b', c', d', will be those described by the eccentric, while the slide takes the positions indicated by a, b, c, d.

But while the eccentric describes the arc $a'\ d'$, the crank of the axletree describes necessarily an equal angle. As that crank must be horizontal or coincide with bD at the end of the stroke of the piston, if from the point p we trace arcs equal to $d'\ c'$, $d'\ b'$ and $d'\ a'$, or in other words, arcs, the sines of which be, dc, db and da; and if we draw radii through the points thus determined, we shall evidently have in A′, B′, C′, and D′ the points where the crank was, while the eccentric passed through the points a', b', c' d'. Letting perpendiculars fall from the points A′, B′, C′, D′, on bD, we shall at last have in A, B, C, D, the corresponding situations which we sought for the piston.

Thus we recapitulate: while the slide passes from the point a, where it begins to intercept the steam, to the point c, where it opens the opposite passage, and to the point d end of the lead; the eccentric will run through the points a', c', d'; the crank, on its circle, will run through the points A′ C′ D′; and, finally, the piston will be successively at the point A, where it ceases to receive the impulse of the steam, at the point C, where it meets it opposing its motion, and at the point D, where it finishes its stroke.

Now, it will not be difficult to express by precise measure the spaces CD and AD, which we have represented above by a and ϵ.

For that purpose, it will be sufficient in practice to trace exactly, and by the scale, the fig. 27, and then to measure the resulting spaces CD, AD.

To obtain those same quantities by calculation, we have

$$AD = bD - bD \cos A'bD,$$

And, at the same time, expressing the arc A′bD by γ,

$$\text{Sin}\ \gamma = \frac{ms}{bp} = \frac{ad}{bp}.$$

But bD is the half stroke of the piston, which we have expressed by l; and bp is the half range of the slide, which we shall express by l'. If, besides, we call a the lead of the slide or cd, and let r represent the lap of the slide over the apertures or ab, ad will be expressed by $a + 2r$. Thus the quantity sought AB or ϵ will be

$$\epsilon = \frac{l}{2} - \frac{l}{2}\cos\gamma,$$

The value of γ being given by the additional equation,

$$\text{Sin}\ \gamma = \frac{a + 2r}{\frac{1}{2}\,l'} = \frac{2a + 4r}{l'}$$

In the same manner we shall have for CD, or a:

$$a = \frac{l}{2} - \frac{l}{2}\cos\gamma',$$

And γ will be known by the equation:

$$\text{Sin}\ \gamma' = \frac{2a}{l'}.$$

The quantities a and ϵ, of which we have made use in the preceding paragraph, will, consequently be determined by the stroke of the piston, the range of the slide, the lead, and the lap, all of which are known quantities. Thus we will be enabled to calculate immediately the effect of the lead, either on the speed or on the load.

Having seen that the speed of the engine will be increased in the proportion of $\frac{l}{l-\epsilon}$, the consequence will be for the augmentation of the speed a ratio of

$$\frac{l}{l-\epsilon}=\frac{l}{\frac{l}{2}+\frac{l}{2}\cos\gamma}=\frac{2}{1+\cos\gamma}.$$

In the same manner, the limit of the load of the engine will be reduced as if the length of stroke of the piston was no more than $l-a-\epsilon$, or

$$l-a-\epsilon=\frac{l}{2}(\cos\gamma+\cos\gamma');$$

And in these two values, the arcs γ and γ' will be given by the above equations, viz.

$$\operatorname{Sin}\gamma=\frac{2a+4r}{l'},\text{ and }\operatorname{Sin}\gamma'=\frac{2a}{l'}.$$

The use of trigonometrical signs might be avoided in these formulæ; but it would make them less convenient for calculation.

In order to apply them, let us take, for example, an engine with a 16 in. stroke, range of the slide 3 in., lap of the slide over the apertures $\frac{1}{8}$ in., and let us suppose a lead of $\frac{5}{8}$ in. given to the engine.

In that case,

$$\frac{2a+4r}{l'}=\frac{7}{12}=0.58333.$$

The arc, the sine of whch is $\frac{2a+4r}{l'}$, is consequently the arc, the sine of which is 0.58333; or, taking the logarithms, it is the arc, the logarithm sine of which is 9.76591.

Seeking that arc in the tables, we find that the logarithm of its cosine is 9.90967; and finishing the calculation, we find

$$\epsilon=8\text{ in.}-8\text{ in.}\times 0.81222=1.50\text{ in.}$$

In the same manner,

$$a=8\text{ in.}-8\text{ in.}\times 0.90906=0.73\text{ in.}$$

Thus, we see that, in this case, the piston is at a distance of $1\frac{1}{2}$ in. from the bottom of the cylinder, at the moment the action of the moving power is taken away from it; and it is at $\frac{3}{8}$ in. when that same power is introduced against it. Fig. 27 constructed by the scale gives the same results.

From what has been said above, the speed will be augmented in the proportion of $\frac{l}{l-\epsilon}$ or $\frac{16}{14.5}$, for all the loads that do not pass the limit of power of the engine thus regulated.

And the limit of that load will be reduced, as if the stroke, from the length that it had, be reduced to the length,

$$l-a-\epsilon=13.77\text{ in.}$$

We find also, by supposing for the engine a lead of $\frac{1}{8}$ in., that the space that the piston has still to travel, when the steam is intercepted, is 0.25 in.; and that the steam is introduced in a contrary direction, when the piston is still within 0.03 in. from the bottom of the cylinder. From thence results that, with the above lead, the speed is augmented in the proportion of $\frac{16}{15.75}$, and that the *maximum* load is diminished, as if the length of the stroke was reduced to 15.72 in.

Let us take, for an example, an engine like Vesta, viz.

d, diameter of the cylinder $11\frac{1}{8}$ in., or 0.927 ft.; 1, stroke of the piston, 16 in., or 1.33 ft.; D, diameter of the wheel, 60 in., or 5 ft.; F, friction of the engine, 187 lbs.

The limit of the load being given by the formula (Chap. V. Art. V. § 4),

$$M=\frac{(P-\rho)\,d^2\,l}{(\delta+n)\,D}-\frac{F}{\delta+n},$$

We see that if the engine work at the effective pressure of 56.5 lbs. per square inch, as we shall have an example of it in a moment, the limit of a load will be

In case of no lead at all	187 t.
In case of a lead of $\frac{1}{8}$ in.	183 t.
In case of a lead of $\frac{5}{8}$ in.	158 t.

In these same circumstances, according to the formula (Chap. V. Art. V. § 1), the velocity of the engine will be as follows:—

The lead of 187 t. will be drawn at a velocity of 13.81 miles an hour.

The load of 183 t., which, if there had been no lead, would have had a speed of 14.03 miles, will have an augmentation of speed in the proportion of $\frac{16}{15.75}$, that is to say, that the speed will be 14.25 miles an hour.

Finally, the speed of the load of 158 t., which, with no lead, would have been 15.54 miles, will, in consequence of the lead, become 17.14 miles per hour.

We see by these results, that the effect of the lead, either in regard to the speed or to the *maximum* load, are only very perceptible when the lead is rather considerable.

§ 3. *Experiments on the Effects of the Lead.*

The foregoing calculation gives us the loss of power produced in the engine in consequence of the lead.

However, no research having as yet been made on the subject, every thing is at present regulated by opinion alone. There are some engine builders that give no lead at all; others only $\frac{1}{16}$, or $\frac{1}{8}$ in. at most; others, on the contrary, give $\frac{5}{8}$ in. or more. Although the lead, if moderately used undoubtedly facilitates the working of the engine, it is also evident, that if carried too far, it must at last stop its effect. For that reason, we resolved to undertake some experiments on the subject.

In our research, we first made use of the Leeds engine, and we made the three experiments of the 15th of August, related above (Chap. V. Art. VII. § 1); the first with a lead of $\frac{1}{8}$ in.; the second with no lead; and the third, with a lead of $\frac{3}{8}$ in. But as the change in the load, in the pressure, and in the inclination of the road, caused naturally much complication in the results, we soon gave up that engine, and took in its place the Vesta. An ingenious apparatus, invented by Mr. J. Gray, of Liverpool, and fixed to this engine, made it easy to change the lead without interrupting the journey; so that, with the same load, and on the same spot, the engine could be tried successively with different leads. This effect was produced by means of three notches, placed more or less backward on the eccentric, and on which the driver might be brought at will, by means of the common catching lever. The first of these notches gave a lead of $\frac{1}{8}$ in., the second of $\frac{3}{8}$ in., and the last corresponded with a lead oi $\frac{5}{8}$ in. To make the difference more remarkable, we endeavored to obtain a comparrison between the first and the third of these positions of the slide.

The reader will recollect that the Vesta engine has the following proportions:—

Cylinders - - - - - - -	$11\frac{1}{8}$ in.
Stroke of the piston - - -	16 in.
Wheel - - - - - - - -	5 ft.

I. On the 16th of August 1834, arriving with the engine and a train of 20 wagons at the foot of the inclined plane of Whiston, the inclination of which is $\frac{1}{89}$, all the train was taken off except the seven first wagons, weighing together 34.43 t., and with the tender, 39.93 t.; and the engine endeavored to ascend the plane with that load.

The lead was first regulated at $\frac{5}{8}$ in. Arrived at the foot of the plane with an acquired velocity of 10 miles an hour, the engine continued its motion for some time, but slackened visibly; and, after having travelled $\frac{3}{4}$ mile, it stopped; the pressure being $23\frac{1}{2}$ lbs. by the balance.

The lead was reduced to $\frac{1}{8}$ in. The engine set off again, and reached the top of the plane with a velocity of 14 complete strokes of the piston per minute, the pressure by the balance being reduced to $23\frac{1}{4}$ lbs.

II. In the evening of the same day, the engine having taken to the same place a train of eight loaded wagons, and 12 empty ones, the eight wagons alone were left attached, their aggregate weight being 27.05 t., and with the tender, 32.05 t. With that load it began the ascent of the plane with an acquired speed of 10 miles an hour.

Lead, $\frac{5}{8}$ in. The engine arrived at the top without stopping. Pressure at the ballance, 23 lbs. Velocity, 46 complete strokes of the piston per minute.

III. The engine having returned to the bottom with the same eight wagons, six empty ones were attached behind them, making with the loaded wagons a total weight of 43.18 t., and tender included, 48.18 t.

This load was too much for the engine, even with its smallest lead. Pressure, 23 lbs. Two of the empty wagons were taken off.

IV. The engine then drew a train of eight loaded wagons and four empty ones, making together a weight of 34.05 t., and tender included, 39.05 t.

A lead of $\frac{5}{8}$ in. was given; the engine was unable to start on the plane.

The lead was reduced to $\frac{1}{8}$ in.; the engine started, and augmented gradually its velocity, giving successively 11 strokes of the piston per minute; then 11 again, then 14, and then 17.

The lead was once more tried at $\frac{5}{8}$ in.; the engine stopped again.

The lead of $\frac{1}{8}$ in. was resumed; the train started again. Pressure during the whole experiment, 23 lbs. by the balance.

V. The train continuing to ascend, two more empty wagons were taken off; there remained then, in all, eight loaded and two

empty ones, weighing together 30.38 t., and with the tender, 35.38t.

Lead, $\frac{5}{8}$ in. The engine stops; pressure, 23 lbs. by the balance.

Lead, $\frac{1}{8}$ in. It starts again; same pressure.

VI. At last one more empty wagon is taken off, and the weight of the train is reduced to 28.55 t., and tender included, to 33.55 t.

Lead, $\frac{5}{8}$ in. The engine stops; pressure, 23 lbs. by the balance.

Lead, $\frac{1}{8}$ in. It starts again, and reaches the top, although, in consequence of the length of the experiment, the pressure diminishes by degrees from 23 to $21\frac{1}{2}$ lbs. by the balance.

The engine executed thus, at $21\frac{1}{2}$ lbs. pressure, what, with a lead of $\frac{5}{8}$ in., it could not execute with a pressure of 23 lbs.

This series of experiments gives us very nearly the exact measure of the power of the engine in both cases, or the loss of power resulting from the difference in the lead.

§ 4. *Table of the results obtained in these Experiments.*

In order to place these experiments together before the eyes of the reader, we unite them in the following table:—

EXPERIMENTS ON THE EFFECTS ON THE LEAD.

Name and designation of the Engine.		Number of the Experiment.	Load of the Engin tender included.	Lead $\frac{5}{8}$ inch. State of the motion.	Lead $\frac{5}{8}$ inch. Effective pressure in pounds per square inch, by the balance.	Lead $\frac{1}{8}$ inch. State of the motion.	Lead $\frac{1}{8}$ inch. Effective pressure in pounds per square inch, by the balance.
			tons.		lbs.		lbs.
VESTA, Cylinders.	$11\frac{1}{8}$ in.	III.	48.18	stopped	20..23 = 56.5	stopped	20. 23 = 56.5
Stroke ...	16 in.	I.	39.93	stopped	20..23.5 = 58	star.agn.	20..23.5 = 57.25
Wheel ...	5 ft.	IV.	39.05	stopped	20..23 = 56.5	star.agn.	20..23 = 56.5
Weight ...	8.71 t.	V.	35.38	stopped	20..23 = 56.5	star.agn.	20..23 = 56.5
Friction ..	187lbs.	VI.	33 55	stopped	20..23 = 56.5	star.agn.	20..21.5 = 52
		II.	32.05	continued its motion.	20..23 = 56.5		

According to those experiments, all that an engine can do with a lead of $\frac{5}{8}$ in., is to draw a load weighing, without the tender, 27.05 t.

And with a lead of $\frac{1}{8}$ in., it will be able to draw a load weighing, without the tender, 34.05 t.

Thus comparing the *useful effects* of the engine in the two cases, we see that they are in the proportion of 4 to 5, which constitutes in practice a considerable advantage in favor of the smallest lead.

In order, however, to obtain an *absolute* measure of the power an engine is able to display in the two circumstances, we must calculate the total resistance that was opposed to the motion of the piston in each case.

In the first, the engine drew a load, tender included, of 32.05 t. on an inclination of $\frac{1}{80}$. On account of the gravity of the mass on the plane, including 8.71 t. for the weight of the engine, the train was equal, on a level, to a load of 160 t.

In the second case the engine drew on the same inclination a train of 39.05 t., equal to a load of 189 t. on a level.

We see that these numbers agree very nealry with those deduced from calulation: If those given by the experiment seem to be a little larger, the reason is because we reckon the tender at an invariable weight of five tons,—whereas, during this long experiment, the consumption of water and coke must have made it descend considerably below that weight, though we had no possibility of weighing the tender, and consequently we could not take the difference into account. We have said, that when the tender is quite empty, its weight is no more than three tons, which upon a level is two tons less than we reckon here, and makes on the inclined plane at $\frac{1}{80}$, a reduction of eight tons in the load.

$$\operatorname{Sin}\gamma = \frac{2\,a + 4\,r}{l'}, \text{ and } \operatorname{Sin}\gamma' = \frac{2a}{l'}.$$

The reader will recollect that in these formulæ the signs have the following significations:

l, length of the stroke of the piston expressed in feet.

a, lead of the slide.

l' length of the range of the slide.

r, lap of the slide over the apertures of the cylinder.

These three last quantities may be indifferently expressed in feet or in inches, the equations containing only their ratio.

Applying, then, these formulæ to a series of different cases, we form the following table, which will show, at a glance, how the velocity increases when the lead is augmented. As, on the other hand, in the second column, we could not go beyond the load the engine is capable of drawing with its supposed lead, the same table also shows what diminution in the maximum load corresponds to that increase in velocity. It is with a view to make the comparison between these two effects more conspicuous, that we have extended the table further than the importance of the subject seems otherwise to require.

We may consequently conclude from experience, as well as from theory, that *the decrease of power occasioned by the lead is in proportion to the resulting decrease in the useful length of the stroke of the piston.*

§. 5. *A Practical Table of the Effects of the Lead.*

In order to facilitate practical researches, we shall calculate here, according to the formulæ laid down above, § 2, a table of the effects of the lead, for different engines of the most usual proportions on railways.

By these formulæ, the velocity of the motion with no lead at all being known, that which will result from a certain lead represented by a, will be to the first in the ratio of

$$\frac{2}{1 + \cos\gamma};$$

but, at the same time, the *maximum* load of the engine will be reduced as if the stroke of the piston were reduced to the length

$$\frac{l}{2}(\cos\gamma + \cos\gamma');$$

The arcs γ and γ' being determined by the equations,

A PRACTICAL TABLE OF THE EFFECTS OF THE LEAD:

DESCRIPTION OF THE ENGINE.	Load in gross tons, tender included	Velocity in miles per hour, the lead being			
		0.	$\frac{1}{8}$ in.	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.
	tons.	miles.	miles.	miles.	miles.
Engine with cylinders 11 in. or 0.917 ft.	50	31.02	31.52	32.51	34.23
Stroke 16 in. or - - - 1.33 ft.	100	21.68	22.02	22.72	23.92
Wheel - - - - - - 5 ft.	141	17.39	17.66	18.22	19.18
Friction - - - - - 120 lbs.	155	16.28	16.54	17.06	0.
Heating surface - - - 140 sq. ft.	163	15.72	15.96	0.	0.
Effective pressure in boiler - 50 lbs.	165	15.58	0.	0.	0.
Range of the slide - - 3 in.					
Lap over the appertures - $\frac{1}{8}$ in.					
Engine with cylinders 12 in. or 1 ft.	50	27.80	28.24	29.13	30.68
Stroke 16 in. or - - - 1.33 ft.	100	20.05	20.37	21.01	22.12
Wheel - - - - - 5 ft.	150	15.68	15.93	16.43	17.30
Friction - - - - - 150 lbs.	168	14.56	14.79	15.25	16.06
Heating surface - - - 140 sq. ft.	183	13.72	13.94	14.38	0.
Effective pressure in boiler - 50 lbs.	193	13.22	13.43	0.	0.
Range of the slide - - 3 in.	196	13.11	0.	0.	0.
Lap over the apertures - - $\frac{1}{8}$ in.					
Engine with cylinders 13 in. or 1.083 ft.	50	29.03	29.49	30.42	32.03
Stroke 16 in. or - - - 1.33 ft.	100	21.46	21.80	22.48	23.68
Wheel - - - - - 5 ft.	150	17.02	17.29	17.83	18.78
Friction - - - - - 165 lbs.	197	14.25	14.47	14.93	15.72
Heating surface - - - 160 sq. ft.	216	13.37	13.58	14.01	0.
Effective pressure in boiler - 50 lbs.	227	12.91	13.11	0.	0.
Range of the slide - - 3 in.	231	12.75	0.	0.	
Lap over the apertures - - $\frac{1}{8}$ in.					
Engine with cylinders 14 in. or 1.116 ft.	50	29.83	30.30	31.26	32.91
Stroke 16 in. or - - - 1.33 ft.	100	22.56	22.92	23.64	24.89
Wheel - - - - - - 5 ft.	150	18.14	12.43	19.00	20.01
Friction - - - - - 180 lbs.	200	15.17	15.41	15.89	16.73
Heating surface - - - 180 sq. ft.	229	13.85	14.07	14.51	15.28
Effective pressure in boiler - 50 lbs.	252	12.96	13.16	13.58	0.
Range of the slide - - 3 in.	265	12.50	12.70	0.	0.
Lap over the apprtures - - $\frac{1}{8}$ in.	269	12.37	0.	0.	0.
Engine with cylinders 12 in. or 1 ft.	50	26.16	26.57	27.41	28.86
Stoke 18 in. or - - - 1.50 ft.	100	19.85	20.16	20.80	21.90
Wheel - - - - - - 5 ft.	150	15.99	16.24	16.75	17.64
Friction - - - - - 165 lbs.	188	13.93	14.15	14.60	15.37
Heating surface - - - 160 sq. ft.	207	13.09	13.30	13.72	0.
Effective presssure in boiler - 50 lbs.	217	12.69	12.89	0.	0.
Range of the slide - - 3 in.	221	12.53	0.	0.	0.
Lap over the apertures - $\frac{1}{8}$ in.					

From these results we see that too great a lead detracts a considerable portion from the power of the engine. It is therefore necessary not to exceed, in that respect, certain limits.

It is, besides, easy to know the lead, or to regulate it at any degree.

After having opened the chamber situated under the chimney, and taken off the top of the slide-box, in order to see the slides work, the engine must be pushed gently forward on the rails, until the crank of the axle be perfectly horizontal.

Then the piston is at the bottom of the cylinder. If at that moment the passages which the slide opens to the steam be measured, it will give exactly the lead.

If we wish to alter the lead, we keep the crank in the same position, and loosening the driver which is fastened to the axle only with a screw, we turn the exccentric, until the slide, which moves at the same time, opens the passage as much as is wanted. Then we replace the driver so as to fix the exccentric in that position. This operation concluded, it is clear that whenever the crank is horizontal, or the piston ready to begin its stroke, the slide will open the passage to the degree required.

There are some ways of altering the lead without opening each time the chimney chamber; but they are not quite exact, and some of them are injurious to the engine.

In the experiments we have related above on the velocity of the load of the engines, the *Vesta* engine was the only one in which the lead was considerable enough to have a remarkable effect on the speed.

CHAPTER VII.

OF THE CURVES AND INCLINED PLANES.

ARTICLE I.

OF THE CURVES.

§ 1. *Of the conical form of the Wheels and surplus of elevation of the Rails, calculated to annul the effect of the Curves.*

We have considered the dispositions proper to the engine, that may either favor or impede its effect. We have still to examine two external circumstances that may have a similar influence on the motions.

The curves offer on the railways an additional resistance, which is so much the greater according as the degree of their incurvation is more considerable.

The wagons being of a square form, tend to continue their motion in a straight line. If, therefore, they are obliged to follow a curve, the flange of the wheel does no longer pass in a tangent along the rail without touching it, as it does in a direct motion. The rail, on the contrary, presents itself partially crosswise before the wheel, and opposes thus its progress, by forcing it to deviate constantly from its direction.

Moreover, the wheel that follows the exterior rail of the curve has naturally more way to travel than that which follows the interior rail. Now. in the wagons at present in use, the two wheels of the same pair are not independent of one another. They are fixed on the axletree that turns with them. If therefore the road travelled by one of the two wheels be less than that of the other, the latter one must necessarily be dragged along without turning on the difference of the two roads.

Finally, on passing the curves, the wagons are thrown by the centrifugal force of the motion against the outward rail, the result of which is a lateral friction of the flange of the wheel against the rail, which does not exist in the direct motion.

It is impossible to construct the wheels of the wagons and the railway itself in such a manner that these three additional causes of resistance may be destroyed. The mode we are going to describe, in order to obtain that effect, is that which is already known; viz., the conicalness of the tire of the wheel, and a greater elevation of the outward rail at the place of the curve. But those means have until now been employed only by approximation, and fulfil more or less imperfectly the intended purpose. By sumitting them to calculation, we trust we shall be able to deduce general rules, which will make us certain that the required effect will be obtained.

The particular resistance owing to the passage of the curves, is composed of two distinct parts, as to their causes and their effects.

The first, according to what we have seen above, is occasioned by the waggons being obliged to turn along the curve, which produces an opposition of the rail to the motion, and a dragging of the wheel.

The second is owing to the centrifugal force, and produces the friction of the flange of the wheel against the rail.

The first of these two resistances will evidently be corrected, if we succeed in constructing the wheels of the wagon in such a manner that the wagon may follow of itself the curve of the railway. For that, it will be sufficient to make the wheel slightly conical with its greatest diameter inside; that is to say, towards the body of the wagon, as appears on the engine in fig. 2.

By that disposition, when the centrifiugal force throws the wagon on the outside of the curve, the wheel on that same side will then rest on a tire of a larger diameter. Two effects will result from this. The wagon will no longer tend to follow a straight line. One of its wheels growing larger than the other, will, on the contrary, have a tendency to turn in the direction of the curve. Besides which, the two coupled wheels will naturally travel different lengths of road without any dragging on the rail.

This form of the wheel and its effects being very well understood, we have first to determine what difference of diameter must be created between the two wheels, in order that the wagon may turn of itself with the curve, and how much the wagon must deviate on one side in order to produce that difference of diameter. Then we shall see how the railway must be constructed, in order that the centrifugal force of the motion produce of itself that lateral deviation. It will thus be clear, that, those different conditions being fulfilled, the first species of resistance of the curve will be destroyed by the motion itself. Coming to the friction of the flange of the wheel against the rail, we shall determine what degree of conicalness the wheel must have, in order that, even in passing over the most abrupt curve of the railway, the lateral deviation of the wagon may never go so far as to put the flange in contact with the side of the rail. In this way, both by the disposition of the rails and by the form of the wheels, the two species of resistance will be destroyed.

Let us suppose that mm' and nn' (fig. 28) be the two lines of rails of the way. In order that the wagon may follow without effort the curve of the way, it is necessary that, while the outside wheels describes the arc mm', the inside wheel describes of itself the arc nn', which terminates at the same radius as the first. If, therefore, the length mm' represent a circumference of the outside wheel, nn' must also be a circumference of the inside wheel, and the diameters of the two wheels must be in a certain proportion for that effect to be produced.

Let D be the diameter of the first wheel, and D′ that of the second, π being the ratio of the circumference to the diameter, we shall have—

$$mm' = \pi\,\mathrm{D}, \text{ and } nn' = \pi\,\mathrm{D}'.$$

Now the two arcs being both terminated by the same radius, we have—

$$\frac{mm'}{nn'} = \frac{mo}{no}.$$

If we express the radius of curvation os by r, and the half breadth of the road by e, this proportion may be expressed thus:—

$$\frac{mm'}{nn'} = \frac{r+e}{r-e};$$

then,

$$\frac{\mathrm{D}}{\mathrm{D}'} = \frac{r+e}{r-e}$$

and, finally,

$$\mathrm{D} - \mathrm{D}' = \mathrm{D}\left(1 - \frac{r-e}{r+e}\right) = \frac{2\,e\,\mathrm{D}}{r+e}.$$

This equation shows the difference that must exist between the diameters of the wheels, that the required effect may be obtained.

Our intention being to produce that effect, by pushing the wagon aside on the road, the question is, how much the wagon must be laterally displaced.

This point depends evidently on the degree of conicalness of the wheel.

At Liverpool, the wheels of the wagons have 3 ft. diameter at the interior part or near the flange, and 2 ft. 11 in. at the exterior part. The wheel is originally cylindrical, but the conical form is produced by the addition of a second tire, the breadth of which, not including the flange, is $\frac{1}{2}$ in. less on one side than on the other. Fig. 29, represents the section of that tire on a scale of $\frac{1}{4}$. Its breadth being $3\frac{1}{2}$ in., we see that its conical inclination is $\frac{1}{2}$ in. on $3\frac{1}{2}$ in. or $\frac{1}{7}$.

Let us suppose in general the inclination of the tire expressed by $\frac{1}{a}$. The two wheels running originally upon equal tires, in order that the difference D—D′ be produced in their diameters, by the displacing of the

tire on the rail, this lateral displacing of the wheel must evidently be

$$\tfrac{1}{4}\, a\,(D - D');$$

for the inclination of the tire being $\frac{1}{a}$, this displacing will produce on the thickness of the tire, or on the radius of the wheel, a difference of

$$\tfrac{1}{4}\,(D - D'),$$

which will make on the diameter

$$\tfrac{1}{2}\,(D - D').$$

This difference on the diameter will be produced in plus on the outside wheel, and as an equul difference, but in a contrary sense, that is to say, in minus, will be produced on the inside wheel; the result will be a total difference of D — D′ between the actual diameter of the two wheels, as we have said.

Thus the lateral motion to be produced is

$$\tfrac{1}{4}\, a\,(D - D) = \frac{a\,e\,D}{2\,(r+e)}.$$

We know at present what must be the lateral displacing of the wagon, in order to destroy the first species of resistance. The question now is, to make use of the centrifugal force to produce that effect. It is its natural tendency; but it is evident that that force must produce exactly the necessary displacing, else the defect would by no means be corrected.

If we represent by r the radius of curvation, by V the velocity of the motion, and by m the mass of the body moved, the centrifugal force produced on the curve will be, as is known, expressed by

$$f = m\,\frac{V^2}{r}.$$

But P being the weight of that same body, and g the accelerating force of gravitation, we have

$$P = gm, \text{ from whence } m = \frac{P}{g};$$

thus

$$f = \frac{P}{g}\,\frac{V^2}{r},$$

which is the expression of the centrifugal force of a body of a given weight P, moving with a velocity V, on a curve the radius of curvation of which is r.

In this expression, g is the accelerating force of gravitation, or the double of the space passed over in the unit of time by a body falling in a vacuum. Taking a second for the unit of time, and a foot for the unit of space, we have $g = 32$. Referring to the same units the velocity V, and the radius of curvation r, we shall have the measure of the centrifugal force expressed by its proportion to the weight P, or represented by a weight.

Let us suppose, for instance, that the velocity of the motion be 20 miles an hour, or 29.3 ft. per second, and the radius of the curve 500 ft.; we shall have

$$f = P \times \frac{\overline{29.3}^{\,2}}{32 \times 500} = \tfrac{1}{19}\,P.$$

So in that case the centrifugal force will be the nineteenth part of the weight of the body in motion.

The sense of the signs being now well understood, we return to the general expression of the centrifugal force.

$$f = P \times \frac{V^2}{gr}.$$

The effort of this force exerting itself in the direction of the radius, its effect will be to push all the wagons out of the curve. If the two sides of the railway are of equal elevation, the wagons will be stopped in the lateral motion only by the friction of the flange of the wheel against the rail. But if we give to the outward rail a surplus of elevation above the inward one, it is clear that, in increasing sufficiently that elevation, we shall be able to master at last the centrifugal force, in such a manner as to permit it only to produce just the displacing we want. In fact, by raising in that manner the outward side, we change the railway in an inclined plane. The wagons placed on that plane ought, by virtue of their gravity, to slip towards the lower rail. On the other hand, the centrifugal force pushes them against the outward rail, which is the highest. We create, then, by that means, a counterpoise to the centrifugal force.

Let us call y the surplus of elevation given to the outward rail (fig. 30); $2e$ being the breadth of the way, the inclination of the plane on which the wagons are placed, is $\frac{y}{2e}$. On this plane, the gravity of a body, the weight of which is P, is expressed by

$$P \times \frac{y}{2e}.$$

This gravity, as we have seen, tends to make the wagons fall within the curve, while the centrifugal force pushes it without. If, therefore, we select the height y, such as may give

$$P \times \frac{y}{2e} = P \times \frac{V^2}{gr},$$

the train, in passing over the curve, will experience no derangement from its original position, because the gravity and the centrifugal force will equilibrate.

But, as for motives already explained, we require the wagon to be pushed aside, a certain quantity expressed by

$$\frac{a\,e\,D}{2\,(r+e)} = \mu,$$

we must endeavor to find out what is the necessary inclination.

Let us then suppose the train already displaced as much as required. Let us imagine, for instance, that the train has been pushed from the position ab to the piston cd (fig. 30;) that is to say, that the point of the inside wheel that was at a be come to c, at the distance μ from the first point, and that at the same time, the point of the outward wheel that was at b, be come to d. In this situation, the inclination of the plane on which the train is, will be $\frac{y}{2e-\mu}$.

Moreover, the conical inclination of the wheels shows that on the outward side of the curve the wheel will have increased its diameter by a certain quantity, in consequence of the lateral deviation; while on the interior side, it will on the contrary, have diminished of an equal quantity. The tire of the wheel having a supposed inclination of $\frac{1}{a}$, a lateral motion represented by μ, must have produced on each wheel a difference in height represented by $\frac{\mu}{a}$. The effect of that variation of the wheels being to incline the wagon on one side, so that it is raised on one side of the quantity $\frac{\mu}{a}$, and lowered on the other of the same quantity $\frac{\mu}{a}$; the result is a total inclination of $\frac{2\mu}{a}$, which must thus be added to the inclination already produced by the difference of level between the rails.

Consequently the outward side of the wagon will be raised above the interior side of a quantity equal to $y+\frac{2\mu}{a}$; and as the base which separates the two bearing points is measured by $2e-\mu$, the final result is that the wagon will be in the same case as if it were placed on a plane, the inclination of which should be

$$\frac{y+\frac{2\mu}{a}}{2e-\mu}.$$

In order that the centrifugal force may maintain the wagon in that position without throwing it out or letting it fall in, that is to say, so that there may be an equilibrium between the gravity on the plane and the centrifugal force, we must have

$$P \times \frac{y+\frac{2\mu}{a}}{2e-\mu} = \frac{PV^2}{gr},$$

or

$$y = \frac{V^2}{gr}(2e-\mu) - \frac{2\mu}{a},$$

Substituting for μ its value, this equation becomes

$$y = \frac{eV^2}{gr}\left\{2 - \frac{aD}{2\,(r+e)}\right\} \frac{eD}{r+e}.$$

Knowing, then, the conical form and the diameter of the wheels, as well as the average velocity of the motion and the breadth of the way, this expression will give the surplus of elevation y that suits the radius of curvation r.

Let us suppose that we have to employ the dimensions of the railway and wagons of Liverpool; that is to say, that we have:

V, average velocity, 20 miles an hour, or 29.3ft. per. second.

$\frac{1}{a}$, inclination of the tire of the wheel, $\frac{1}{7}$.

e, half breadth of the way, 2.35 ft.

D, diameter of the wheel at its right place on the rail, 3 ft.

If we wish to construct on that railway a curve of 500 ft. radius, on which the wagons may experience no additional resistance the equation will give

$y = 0.236$ ft. or in inches, $y = 2.83$ in.

We must, therefore, for that curve, with that wheel and that average velocity, give a surplus of elevation of 2.83 in. to the outward rail.

Adopting the surplus of elevation of the rail deduced from that equation, we render it impossible, the first species of resistance, which the passage of the curves tend to produce. However, as we only destroy that resistance by a certain lateral deviation of the wagon, it might be feared that that deviation might go so far as to make the flange of the wheel rub against the rail, in which case we would only have substituted one resistance for another. This is, therefore, the point we have still to consider.

We have, until now, supposed the inclination $\frac{1}{a}$ of the tire of the wheel to be given *a priori*. But as it is on that inclination that depends the degree of deviation the wagon must undergo on the rails, it must evidently be such that, even on the most abrupt curve of the line, the lateral deviation of the wagon may never be considerable enough to bring the flange of the wheel in contact with the rail.

Now we have seen above, that the necessary lateral deviation is expressed by

$$\mu = \frac{aeD}{2(r+e)};$$

If, therefore, the wagons have, for instance, a play of 2 in. on the way altogether; that is to say, if, in their regular position, the flanges of the wheels keep on each side at a distance of 1 in. from the rail, the greatest value of the deviation μ, must always be less than 1 in. By that greatest value of μ, we mean the deviation on the most abrupt curve of the line. Consequently, putting for r the radius of that curve, and for μ its maximum, 1 in. or $\frac{1}{12}$ of a foot, the equation will give the greatest value that can be given to the quantity a, or the least value of the inclination $\frac{1}{a}$.

For instance, on a line, the most abrupt curve of which has 500 ft. radius, with wagons having wheels of 3 ft. diameter, and a play of 1 in. on each side of the way, the equation shows that the least inclination one ought to give to the tire of wheel is $\frac{1}{12}$; but a more considerable inclination will answer, *a fortiori*.

On the Liverpool and Manchester Railway, the most abrupt curve, which is the one at the entrance of Manchester, has a radius of 858 ft. This results a conical inclination of $\frac{1}{12}$, and this would answer in all cases; but having said that a greater inclination will fulfil the same object, we are free to adopt a greater inclination, if it suits other purposes better.

It is customary to give an inclination of $\frac{1}{7}$. The motive for making it so considerable, is to prevent all possibility of the flange rubbing against the rail, either in case of a strong side-wind, or in case of some fortuitous defect in the level of the rails, by which the wagons would be thrown on the lower rail. Having seen above that, with an inclination of $\frac{1}{12}$, there would be no danger of the flange rubbing in the curves, that danger will be still more impossible with an inclination of $\frac{1}{7}$.

We conclude that, with wheels having that inclination, the surplus of elevation of the rail which we have determined above, will correct the first species of resistance of the curves without creating the second, and that, consequently, the train will pass over the curves without any diminution of speed.

§ 2. *A Practical Table of the Surplus of Elevation of the outward Rail in Curves, in order to annul the effects of those Curves.*

From what has been said, the surplus of elevation that must be given to the outward railin the curves, is determined by the following formulæ:

$$y = \frac{eV^2}{gr}\left\{2\,\frac{aD}{2(r+e)}\right\}\frac{eD}{r+e}.$$

In this equation the signs have the following value:

D, diameter of the wheel expressed in feet.
r, radius of the curve expressed in the same manner.
e, half of the width of the way expressed in the same.
V, average velocity that is to be given to the motion, expressed in feet per second.
g, accelerating force of gravitation, expressed in feet per second, or $g = 32$ feet.
$\frac{1}{a} = \frac{1}{7}$; consequently, $a = 7$.

y, surplus of elevation to be given to the outward rail of the curve, over the inward rail, expressed in feet and decimals of feet.

Solving these formulæ in the most usual cases on railways, we make out the following table which dispenses with all calculations in that respect.

A PRACTICAL TABLE OF THE SURPLUS OF ELEVATION TO BE GIVEN TO THE OUTWARD RAIL IN THE CURVES, IN ORDER TO ANNUL THE RETARDING EFFECT OF THE CURVES.

Designation of the Wagons and the Way.	Radius of the curve, in feet.	Surplus of elevation to be given to the rail, in inches, the velocity of the motion in miles, per hour, being		
		10 miles.	20 miles.	30 miles.
	ft.	in.	in.	in.
Wagon with wheel . . . 3 ft.	250	1.14	5.60	12.99
Way . . . 4.70 ft.	500	0.57	2.83	6.56
Play of the wagon on the way, 1 in., or . . . 0.083 ft.	1000	0.29	1.43	3.30
Inclination of the tire of the wheel $\frac{1}{7}$	2000	0.15	0.71	1.65
	3000	0.10	0.47	1.10
	4000	0.07	0.36	0.83
	5000	0.06	0.28	0.66

ARTICLE II.

OF THE INCLINED PLANES.

§ 1. *Of the Resistance of the Trains on Inclined Planes.*

Inclined planes are a great obstacle to the motion on railways.

As soon as the trains reach these inclined planes, they offer a considerable surplus of resistance, on account of the gravity of the total mass that must be drawn up the plane.

Let us suppose a train of 100 t. drawn by an engine. Having seen that on a level the friction of the wagons produces a resistance of 8 lbs. per ton, the power required of the engine will be 800 lbs., when travelling on a level. But let us suppose the same train ascending an inclined plane at $\frac{1}{100}$. On that plain, besides the resistance owing to the friction of the wagons, a fresh resistance occurs, which is the gravity of the total mass in motion on the plane. That gravity is the force by virtue of which the train would roll back if it were not retained; and it is equal to the weight of the mass divided by the number that indicates the inclination of the plane. If, therefore, in this case, the load of 100 t. is drawn by an engine weighing 10 t., the total mass placed on the inclined plane will be 110 t. or 246,400 lbs.; and thus its gravity on the inclined plane, at $\frac{1}{100}$, will be $\frac{246,400}{100}$ lbs. = 2,464 lbs. The surplus of traction required of the engine, on account of that circumstance, is, therefore, 2,464 lbs., and, as we have seen that on a level 1 t. load is represented by 8 lbs. traction, we also see that those 2,464 lbs. represent the resistance that would be offered by a load of 308 t. on a level. Consequently the engine which, before, drew 100 t. must now draw 408 t., or at least must exert the same effort as if it drew 408 t. on a level.

This is the manner in which the calculation of the resistance on inclined planes must be established; and we have entered into those particulars, because it frequently happens that, in making the calculation, the gravity of the load is alone considered, without taking into account the gravity of the engine, which ought also to enter for its share.

In speaking of the fuel, we shall see that the inclined planes of the Liverpool Railway, which at first sight appear quite insignificant, oblige, however, the engines to a surplus of work, which amounts to a sixth part of what they would have to do on a level. By this we see how important it is, in establishing a railway, to keep it on as perfect a level as possible. It frequently happens that, by avoiding to level a part of the road, that is to say, to cut through a hill, or to form an embankment through a valley, a great economy is expected. This is, however, a great mis-

take, for, in most instances, the only economy is that of the first outlay, whereas, the annual augmentation of expense surpasses by far the interest of the capital saved; so that, instead of an economy, we have in reality a greater expense. This additional expense may even, in some cases, go so far as to paralyze completely all the advantages of the undertaking.

In suffering inclined planes to subsist on a line of railway, it not only becomes impossible to lower sufficiently the freight of the goods; but, what is much more important, frequent accidents occur while descending those steep acclivities, the least inconvenience of which is to destroy public confidence in the safety of the conveyance. It is, therefore, necessary to lay down as a principle, that the end to be aimed at in the construction of a railway, is not only to make a smooth road, but likewise a level one. It is, besides, the only way to apply with efficacy the use of locomotive engines.

When, however, it has been impossible to avoid the inclined planes, and when the use of stationary engines has been rejected on account of the interruption they unavoidably cause in the service, there are only two ways that can be resorted to. The loads must either be regulated so that they may not exceed the power of the engine in going up the plane, or it is necessary to give the engines the help of one or more others, according to what is required.

On the Liverpool Railway, the trains of coaches never being very heavy, are seldom above the power of the engines on the most inclined parts of the line, viz. in the two acclivities of $\frac{1}{96}$ and $\frac{1}{89}$. In general, therefore, the engines ascend these inclined planes without help; and during the rest of the trip, on the level or descending parts of the line, their speed is regulated by partially shutting the regulator.

The trains that are too heavy for a single engine, as are commonly those of wagons, are helped in passing the plane by an engine stationed at the foot of the acclivity, and especially intended for that use. This engine is, consequently, constructed for a slow motion and a considerable power. The cylinders have 12 or 14 in. diameter, with the usual stroke of 16 in., and the wheels have only 4 ft. 6 in. Besides, in order to have more adhesion, the weight of the engine is 12 t. and the four wheels are coupled. These additional engines, working less than the others, require also, in general, much less repairs.

On the Darlington Railway, the acclivities are much too numerous for an additional engine to be placed at each of them. The load of the engine must therefore be limited so that it may ascend with that load the most inclined of the planes.

The locomotive engines acquire, however, a considerable augmentation of power, at the moment of their passage on an inclined plane, because their speed being suddenly considerably reduced, the cylinders consume a smaller quantity of steam. The fire, strongly excited by the preceding rapidity of the engine, continuing to furnish the same quantity of steam, a great part of it must escape through the valve. But the passage of the valve is too narrow to emit freely all that steam. Besides, the spring that presses on the valve opposes more and more resistance, in proportion as the steam tends to raise it higher, in order to get a wider passage for itself. The consequence is that the steam, not being able to escape as quickly as it is generated, suffers an increase of pressure in the boiler.

This increase of pressure evidently depends on several circumstances: the size of the valve, the evaporating power of the boiler, the previous excitation of the fire, and finally the length of the lever at the extremity of which the spring-balance acts. In some engines this increase may amount to 10 lbs. per square inch, as we have remarked in speaking of the pressure.

In that case, if the usual effective pressure of the engine be 50 lbs. per square inch, it may, on ascending the inclined plane, increase to 60 lbs., that is to say, in the proportion of $\frac{1}{5}$, which is considerable. This must, therefore, be taken into account when it is required to calculate the load the engines are able to draw on these planes. But it is necessary to observe that this is effectual only when the inclined planes are not of too considerable an extent, because, in that case, the fire ceasing to be excited in the same proportion, the surplus of effect will be reduced. The weight of the engine must, besides, always give sufficient adhesion of the wheel to the rail, as we shall explain in the following Chapter.

those weights being limited either by the power of the engine, as we have explained

There is also another circumstance in which the engines are obliged to exert an additional effort. That is at the moment of starting. We have seen, in fact, that the power which, when the motion is once created, need only to be constantly equal to the resistance, must, on the contrary, surpass it at the instant that it is to put the mass in motion. The reason is plain: in the first place, it is only necessary to maintain the speed; in the other it must be created and maintained. It is this additional effort on the part of the moving power which is improperly called *vis inertiæ*, because it is attributed to a particular resistance residing in the mass.

The starting is, therefore, a difficult task for a locomotive engine heavily loaded. However, at that moment the engine acquires, as well as on the inclined planes, a considerable increase of power. Here again the slowness of the motion produces two effects. The pressure in the cylinder grows equal to the pressure in the boiler, which is itself augmented by the effect of the spring-balance. But, notwithstanding this twofold advantage, the difficulty of starting still remains so great for considerable loads, that we should always advise giving in that point a slight declivity to the way. By that means the trains would be set in motion with more ease at the departure, and it would not be necessary at their arrival to make use, in order to stop them, of the powerful brakes, the effect of which is certainly as destructive to the wheels of the wagons as to the rails.

§ 2. *Practical Table of the Resistance of the Trains on Inclined Planes.*

In the preceding paragraph, we have seen in what manner the resistance of the trains on the inclined planes must be calculated. The following table presents the result of that calculation in the cases which occur the most frequently on the railways.

It is clear that, by the weights inscribed in the following table, it is only intended to show the resistance offered by the train, and not the weights the engines are able to draw, elsewhere, or by its adhesion, as shall be mentioned in the following Chapter.

This table, assimilating the trains drawn on inclined planes, to trains drawn on a level, gives the means to learn by the former tables, either the loads the engines will be able to draw on given inclinations, or, *vice versa*, the inclined planes the engines will be able to ascend with given loads.

A PRACTICAL TABLE OF THE RESISTANCE OF THE TRAINS ON INCLINED PLAINS.

Designation of the Engine.	Weight of the trains in gross tons, tender included.	Load in gross tons which on a level would offer the same resistance the inclination of the plane being					
		$\frac{1}{500}$	$\frac{1}{400}$	$\frac{1}{300}$	$\frac{1}{200}$	$\frac{1}{150}$	$\frac{1}{100}$
Engine weighing 8 t. - - -	25	44	48	56	71	87	117
	50	83	91	105	131	158	212
	75	122	133	153	191	230	307
	100	161	176	201	251	302	402
	125	200	218	249	311	373	497
	150	239	261	298	371	445	592
Engine weighing 10 t. - -	25	45	50	58	74	91	123
	50	84	93	107	134	162	218
	75	123	135	155	184	234	313
	100	162	178	203	254	306	408
	125	201	220	251	314	377	503
	150	240	263	300	374	449	598
	175	279	305	348	434	521	693
	200	318	348	296	494	592	788
Engine weighing 12 t. - -	25	46	51	60	77	95	129
	50	85	94	109	137	166	224
	75	124	136	157	197	238	319
	100	162	179	205	257	310	414
	125	202	221	253	317	381	509
	150	241	264	302	377	453	604
	175	280	306	350	437	525	699
	200	319	349	398	497	[illegible]96	794
	225	358	392	446	557	668	889
	250	397	434	494	617	740	984

CHAPTER VIII.

OF THE ADHESION.

§ 1. *Measure of that Force.*

The series of experiments we have described above on the velocity and load of the engines, solves also another question in regard to the motion of locomotive engines of which we have not yet spoken. That is the adhesion of the wheel to the rails.

We have remarked in describing the engine, that the power of the steam being applied to the wheel, the engine is in the same situation as a carriage which is made to advance by pushing at the spokes. Thus, as in that action, the only fulcrum of the

moving power exists in the adhesion of the wheel to the rail, if that adhesion is not sufficient, the force of the steam will indeed make the wheels turn, but the wheels, but the wheels slipping on the rails instead of adhering to them, will revolve, and the engine will remain in the same place.

The more considerable the train the engine draws, the more power it must employ, and the more resistance it must consequently find in the point on which it rests, for executing the motion. It was therefore to be feared, that with considerable trains, the engines would be unable to advance ; not that the force would be wanting in the moving power itself, but in the fulcrum of the motion.

The experiments related above, establish the measure of that adhesion in the fine season of the year. Among all these experiments, not one is to be found where the motion has been stopped or even slackened for want of adhesion, and nevertheless we see loads that amount to more than 200 t.

If we take, for instance, the first experiment made with the FURY, on July 24 ; during a part of the journey, that engine drew 244 t. The engine advancing with that load, the adhesion must necessarily have been sufficient. Now the weight of the FURY is 8.20 t,, and that weight is divided in such a manner, that 5.5 t. are supported on the two hind wheels, which are the only working wheels, the others not serving to push the engine forward, but only to carry it. We have thus a weight of 5.5 t. drawing 244 t., or a load $44\frac{1}{2}$ times as considerable as itself. The result of this is, that an engine having its four wheels coupled, and which consequently adheres by its whole weight, is able to draw a load $44\frac{1}{2}$ times its own mass.

We have said that the FURY engine adhered only by two of its wheels. On the Liverpool Railway that disposition is generally adopted for all trip engines, because the adhesion of two wheels is sufficient for the loads they have to draw. As for the helping engines, the work by the adhesion of their four wheels, as has been said elsewhere. The ATLAS is the only one of the former class that differs from the others in that respect. This engine has six wheels, four of which are of equal size, and worked by the piston. The two others, which are smaller, and have no flange, can be raised out of contact with the rails, by the action of the steam on a moveable piston. That ingenious arrangement, which may have more than one useful application, in permitting the weight of an engine to be distributed upon six wheels, without making the engine more embarrassing than if it had only four, is due to Mr. J. Melling, of Liverpool, who, in this instance, made use of it in order to give the engine a much larger firebox, and consequently the power of generating a greater quantity of steam.

We have now expressed the adhesion, by giving the measure of its effects ; but the power itself may be expressed in a direct manner. The load of 244 t. produced a resistance, or required a traction of 1,952 lbs. ; the adhesion was thus equal at least to 1,952 lbs., else the wheel would have turned without advancing. Now the adhering weight was 5.5 t. or expressed in pounds 12,320 lbs. ; we see then that the force of adhesion was equal to about $\frac{1}{6}$ of the adhering weight. Considering that every 8 lbs. force corresponds with the traction of a ton on a level, this expression is exactly similar to the first.

In winter when the rails are greasy and dirty, in consequence of damp weather, the adhesion diminishes considerably.—However, except in very extraordinary circumstances, the engines are always able to draw a load of 15 wagons, or 75 t., tender included, that is to say, 14 times their adhering weight. In other words, the resistance of 75 t. being 600 lbs., the force of adhesion is always at least $\frac{1}{20}$ of the adhering weight.

Adhesion being indispensable to the creation of a progressive motion, two conditions are necessary in order that an engine may draw a given load. 1st. That the dimensions and proportions of the engine and its boiler enable it to produce on the piston, by means of the steam, the necessary pressure, which constitutes what is properly termed the power of the engine: and, 2nd, that the weight of the engine be such as to give a sufficient adhesion to the wheel on the rail. These two conditions of power and weight must be in concordance with each other ; for, if there is a great power of steam and little adhesion, the latter will limit the effect of the engine, and there will be steam lost ; if, on the other hand, there is too

much weight for the steam, that weight will be an useless burthen, the limit of load being in that case marked by the steam.

§ 2. *Of the Engines employed on Common Roads.*

The considerable loads that have been drawn by the engines in the experiments described above, ought to remove the fears of such persons as suppose that the wheels of locomotive engines on railways are constantly apt to slip, and who endeavor to remedy that imaginary defect by employing the engines on common roads, without having ascertained whether the adhesion will be more considerable.

We see here a locomotive engine on a railway, drawing 244 t. by the force of its steam, and not less than 75 t. by its adhesion. Its loads are thus always comprised between those two limits.

On a common road, where the resistance of traction is very considerable, not one of the above-mentioned engines would be able, by the force of its steam, to draw a weight of 75 t., much less ever to attain 244 t. The loads will therefore always, and in every circumstance, remain below what they would be on a railway. Of what importance is it, in fact, whether the moter gains in regard to adhesion, which is only an inert force, if the power of the steam do not enable it to profit of that advantage?

We say that an engine that draws on a railway a load of 75 t. *at least*, will never be able, on a common road, to draw that same load *at most*.

Let us in fact examine the same engine, with the same weight and same pressure, placed in those two different circumstances.

The experiments made by Mr. Telford, on the draft of carriages on different sorts of roads, prove that on the road from Liverpool to Holyhead, *the best in England*, the force of traction necessary to draw a weight of one ton is as follows:—*

	lbs.
1st. On a well-made pavement - -	33
2nd. On a broken stone surface on old flint road - - - - - - - - - -	65
3rd. On a gravel road - - - - -	147
4th. On a broken stone road, upon a rough pavement foundation - - -	46
5th. On a broken stone surface upon a bottoming of concrete, formed of Parker's cement and gravel - -	46
Mean - - - - -	67

On a railway, a ton requires only 8 lbs. traction. Thus, on the Holyhead road, the traction of a ton requires eight times as much force as on a railway.

The consequence is, that the FURY engine, for instance, which by the effect of its 65 lbs. effective pressure, was able to draw on a level 244 t., would in no circumstance, even on the excellent Holyhead road, be able at the same pressure to draw more than $\frac{1}{8}$ of that load, or 30 t.

Thus its *maximum* load on a common road would only be the $\frac{2}{5}$ of its *minimum* load on the railway.

To which must still be added, that the resistance of the engine in the case of its progress on a common road, will be, like the resistance of the wagons, considerably augmented. It will therefore be obliged, in order to move itself, to consume a much greater portion of its own power, which will diminish in the same proportion the 30 t. it might else have drawn.

We see that on a common road, the resistance of the carriages puts much quicker a stop to the useful effect than the adhesion does on a railway; and that, under all circumstances, the advantage in regard to the load is in favor of the engines on railways.

But there is another consideration that appears to militate in favor of what is called steam-carriages, that is to say, locomotive engines employed on common roads; that consideration is the expense of constructing a railway which is thus avoided. A considerable economy is expected to be made by that means. The construction and keeping in repair of the railway, is in fact a very heavy expense. The capital laid out for that will be entirely avoided. But, at the same time, the chief advantage of the undertaking will be lost.

Why demur to lay out capital, if a considerable profit is to be derived from it? Why save the first expense, if the consequence is the necessity of spending more annually than the interest of the capital saved?

This is exactly the present case. The construction of a railway is undoubtedly

* Report of the Holyhead Road Commissioners.

expensive; but it is the principal element of success. It is money employed to level the road, in order not to have any difficulty afterwards in conveying the goods, and to begin from that moment to reap the profits. What would be said to a man who should propose to cross the fields, in order to avoid the constructing of roads? The answer would be, that the loss in freight would be greater than the expense of construction.

The same is true in regard to railways. If there be an advantage in constructing them for horses, as an experience of sixty years' prosperity has sufficiently demonstrated, how is it possible that there should be none for the use of locomotive engines or any other moter? Whatever advantage those engines may offer on common roads, they must necessarily present a much greater one on railways.

It may appear surprising to see a steam-engine on a common road draw two or three stage coaches with 12 or 15 passengers in each. But the Liverpool engines at the time of the races have drawn as much as 800 persons in a single train, at a speed of 15 miles an hour.

It will perhaps be said that steam-carriages are able to draw more than three stage-coaches. As yet, however, none have been fouud that have done more. The greatest part of them do not even carry more than 18 or 20 passengers. It is easy to see the cause that puts so soon a limit to their load. There exists no common road without considerable acclivities. As they must be overcome, it is necessary to give to the engine only the load which it can take over the steepest of those ascents. Now, on an acclivity of $\frac{1}{12}$, the weight of three stage-coaches, or 9 t., increased by the weight of the engine, presents, on account of the gravity, a resistance equal to that which 45 t. or 15 stage-coaches would offer on a level. A steam-engine that is to draw three stage-coaches during a journey of some length, must therefore be able to draw 15 loaded stage-coaches on a level common road. This is all that can be supposed, even admitting improvemen s, for that force corresponds with 120 stage-coaches on a railway. We must take therefore two or three stage-coaches at most, as the regular load of these engines.

But the levelling, which is the result of the expense attending the construction of a railway, renders those same engines capable of drawing 40 loaded stage-coaches or wagons. This is thus 12 or even 20 times as much. To do the same work on a common road, 12 times as many engines will consequently be required at once, with 12 times as many engine-men and fire-men. Considering also the disadvantage there is for the engines, in respect to fuel, in drawing small loads, we may confidently calculate that the expense for fuel will be doubled. Of this we will be the more convinced, if we take into account the surplus of power necessary to move the engine itself on a road full of asperities.

Besides the repairs of the engines are, even on railways, a considerable expense. At Liverpool, of the 30 engines belonging to the company, ten only are in *activity* on the line for the conveyance of goods and passengers. The effective work is eight or ten hours a day, and the expense for maintaining in activity those ten engines, amounts to more than £18,000, or £1,800 a year for each of them. These expenses are paid and become a source of profit, because on a railway the engines draw considerable trains; but it would not be the same thing if the trains were reduced, or, in other words, if a greater number of engines were required to do the same work. Moreover, if the engines, instead of sliding without jolts on the smooth surface of a railway, were obliged to run on the rough soil of our roads, how great would not be the expense of repairs. And we have 12 times as many engines to repair.

Outlay and interest of capital for engines, salary of engine-men and assistants, fuel, repairs, all these articles will soon have absorbed the expected economy.

Besides, the chief advantage of such undertakings, consists in the speed with which the haulage is executed. When the $29\frac{1}{2}$ miles between Liverpool and Manchester were travelled in four hours, there were about 450 passengers going daily from one of those towns to the other. At present when, thanks to locomotive engines, the journey is completed in an hour or an hour and a half, there are 1,200 passengers a day. The speed has the greatest share in the creation of that profit. It must be given up if the engines are only to run eight or ten miles an hour.

Now, the 8 or 9 t. that the locomotive engines weigh on railways, allow us to give them a sufficient extent of boiler to generate a certain quantity of steam per minute, and consequently a certain speed. If the nature of the road obliges us to reduce the weight of the engine to 3 t. only, with the necessity of making all its different parts stronger, on account of the jolts on a rough surface, there will naturally be less heating surface in the boiler, and consequently less possible speed. And, in fact, the steam coaches scarcely do more than eight or ten miles an hour.

As a last reflection we shall add, that until the present moment the success of locomotive engines on common roads, continues, as a speculation, to be very uncertain, whilst the prosperity of railways, whatever be the moving power, is demonstrated by their continued extension. Steam-coaches may be improved, but, we repeat, whatever be the advantages they may offer on a common road, it is not to be contested that, by employing them on a railway, those advantages will be infinitely greater.

CHAPTER IX.

OF THE FUEL.

§ 1. *Of the Consumption of Fuel in Proportion with the Load.*

We have still an important article to discuss. That is the fuel.

From what we have said above, the steam generated in the boiler at whatever pressure it may be, takes, in passing into the cylinder, a pressure exactly determined by the resistance on the piston. The mode of action of the engine, is thus limited to the transformation of a certain quantity of steam, drawn from the boiler, and consequently at the pressure of the boiler, into steam at a lower pressure and of a proportionally greater volume.

Let us suppose the same engine, with the same pressure in the boiler, and travelling the same distance with two different loads. The distance travelled being the same, the number of turns of the wheel, and consequently of strokes of the piston or cylinders of steam expended during the journey, will be the same in the two cases. If the load had been the same, there would also have been identity in the nature of the steam expended. But as the loads differed, the same number of cylinders will indeed have been expended, but the degree of the steam in the cylinders will be different in the two cases.

Then the expense of moving power will be in one case a certain volume of steam at the pressure R, for instance, and in the other case the same volume at the pressure R′.

The pressure of the steam in the boiler being supposed the same in the two experiments, its temperature will also be the same. As the temperature experiences no reduction during its passage to the cylinders, the pipes and the cylinders themselves being immersed in the boiler, or surrounded by the flame of the fire-place, the temperature of the steam in the cylinders will be the same in the two cases.

Thus the volume and temperature of the steam expended during the journey will be the same in both circumstances. The pressure of the steam in the cylinder will alone have undergone a change. Consequently the mass or weight of steam expended, will be in each case in the ratio of the pressure in the cylinder.

The weight of the steam being equal to that of the water that generated it, the weights of water evaporated will then be to each other as the pressures in the cylinder, or, in other words, as the resistances on the piston. Besides as the water is first transformed into steam at the pressure of the boiler, that is to say, in both cases into steam at the same degree of pressure, it follows also that the quantities of fuel necessary for the evaporation, will be to each other as the pressures or total resistances on the piston.

This shows that the consumption of fuel is independent of the speed, and that it depends only on the resistance on the piston.

If in the two journeys we consider, the pressure happens not to be identically the same in the boiler, there will be a little more fuel consumed in that case where the pressure has been the greatest, because the pressure could only increase in consequence of an increase of temperature. But as degrees of pressure very distant from each other are produced by very similar temperatures, the difference of consumption occasioned by that circumstance will be of little importance, and will not be perceived in practice.

This principle gives the proportions of the consumption of fuel for the same engine with different loads, and may thus serve to determine its consumption in all circumstances, as soon as it is known in one determined case.

If for instance Q and Q′ are the quantities of fuel expended with two given loads, the resistance on the piston with the first of these loads being expressed by R, and with the second by R′, we shall have

$$\frac{Q}{Q'}=\frac{R}{R'}$$

But we have already calculated the resistance R on the piston of an engine. We have seen (Chap. V. Art. II.) that M being the load expressed in tons, tender included; F the friction of the engine without load; d the diameter of the cylinder; D the diameter of the wheel; l the length of the stroke; ρ being the atmospheric pressure per unit of surface, n the resistance of the load per ton, and δ the additional friction of the engine per ton of load, that resistance is

$$R=[F+(\delta+n)\,M]\,\frac{D}{d^2l}\times\rho.$$

Thus, for a different load drawn by the same engine, we shall have

$$R'=[F+(\delta+n)\,M']\,\frac{D}{d^2l}+\rho\,;$$

consequently,

$$\frac{Q}{Q'}=\frac{[F+(\ +\delta n)\ M']\ \frac{D}{d^2l}+\rho}{[F+(\delta+n)\ M']\ \frac{D}{d^2l}+\rho}.$$

This equation can be written in the following form:

$$\frac{Q}{Q'}=\frac{M+\left[\frac{\rho\,d^2l}{(\delta+n)\,D}+\frac{F}{\delta+n}\right]}{M'+\left[\frac{\delta\,d^2l}{(\delta+n)\,D}+\frac{F}{\delta+n}\right]}$$

So that the expression

$$\left\{\frac{\rho\,d^2l}{(\delta+n)\,D}+\frac{F}{\rho+n}\right\}$$

being calculated once for all the given dimensions of the engine, nothing more will be necessary than to add that quantity to M and M′, in order to have the required proportion of Q to Q′.

Let us suppose, for instance, that we have an engine similar to the 11-inch cylinder engine of Liverpool, viz.:

F, friction of the engine without load - - - = 110 lbs.
d, diameter of the cylinder 11 in., or in feet - - - - = 0.917 ft.
D, diameter of the wheel = 5 ft.
l, length of the stroke 16 in., or in feet - - - - = 1.33 ft.
As besides we have
ρ, atmospheric pressure per square foot - - - =23.117 lbs.
n, resistance of the load per ton - - - - - - - = 8 lbs.
δ, additional friction of the engine per ton of load = 1 lb.

For this case we shall have

$$\frac{\rho\,d^2l}{(\delta+n)\,D}+\frac{F}{\delta+n}=65.$$

In the case of a 12-inch cylinder engine, with 152 lbs. friction, like the Atlas, the value of this quantity would be 80.

And, finally, for the Vesta, with 11$\frac{1}{8}$ inch cylinders and 187 lbs. friction, the same quantity is 75.

Thus, in the case of those different sorts of engines, we shall have for the quantity of fuel expended with two different loads M and M′,

$$\frac{Q}{Q}=\frac{M+65}{M'+65},$$

or

$$\frac{Q}{Q}=\frac{M+80}{M'+80}.$$

or finally

$$\frac{Q}{Q}=\frac{M+75}{M'+75}.$$

In these expressions M stands for the load, tender included; the weight of the tender is meant, therefore, to be added to the load, if it was not included in it from the first.

We easily perceive that the quantity $\frac{F}{\delta+n}+\frac{\rho\,d^2l}{(\delta+n)\,D}$ is nothing but the friction of the engine and the atmospheric pressure referred to the velocity of the engine, and represented by the number of tons that would offer an equivalent resistance. Thus the number M of tons, added to that quantity represents the total resistance overcome by the engine. Consequently the principle established above amounts to this: that the power applied is in proportion to the *total* resistance to be overcome, as was naturally to be expected.

This invariable quantity, which must be added to the load, expresses, as we have said, the aggregate inert resistance of the engine, or, if we may be permitted to use that expression, the *constant vis inertiæ* of the engine. As this quantity differs for each engine, and as it must be calculated separately for each of them, we shall join here a table which will show its value, superseding thus the necessity of calculating it, for the engines most commonly used on railways.

A TABLE OF THE CONSTANT VIS INERTIÆ OF THE ENGINES, NECESSARY TO DETERMINE THE CONSUMPTION OF FUEL WITH DIFFERENT LOADS.

Designation of the Engine.	*Constant vis inertiæ,* expressed in tons.
Engine with cylinders 11 in., or in feet . . 0.917 ft. stroke 16 in., or 1.33 ft. wheel . . . 5 ft. friction . . . 120 lbs.	66 t.
Engine with cylinders 12 in., or . . . . . . 1 ft. stroke 16 in., or 1.33 ft. wheel . . . 5 ft. friction . . . 150 lbs.	80 t.
Engine with cylinders 13 in., or . . . . 1.083 ft. stroke 16 in., or 1.33 ft. wheel . . . 5 ft. friction . . . 165 lbs.	92 t.
Engine with cylinders 14 in. or . . . . . 1.166 ft. stroke 16 in., or 1.33 ft. wheel . . . 5 ft. friction . . . 180 lbs.	105 t.
Engine with cylinders 12 in., or . . . . . . 1 ft. stroke 18 in., or 1.50 ft. wheel . . . 5 ft. friction . . . 165 lbs.	107 t.

§ 2. *Experiments on the Quantity of Fuel consumed by the Engines.*

The above formula, which is of easy application, gives the absolute quantity of fuel required by an engine in all circumstances, provided the consumption of the engine in a given case be known.

The only thing necessary, will therefore be, to make one experiment on the fuel consumed by the engine with a given load, which will be the data of the problem.

Evidently between two different engines, this first data will differ according to the particular construction of each engine, and chiefly according to the extent of heating surface of its boiler. The following experiments were therefore undertaken on the Liverpool and Manchester Railway, in order to obtain a knowledge of this data, and likewise to verify the theoretical principle exposed above.

In these experiments the tender was first carefully emptied, then the coke was accurately weighed and put into the tender. The fire-place of the engine was besides filled with fuel, up to the lower part of the door. At the end of the experiment, the fire-place was again filled to the same height, and the coke remaining in the tender was weighed with the same care as at setting off.

As an engine that ascends alone, with its train, an inclined plane exerts necessarily a greater effort than if at that moment it were helped by an additional engine, we have put down whether the engine was helped or not in going up the plane. We have also inscribed the state of the weather and the temperature of the water in the tender, in order that those circumstances might be taken into consideration.

In these experiments, the co-operation of the persons attached to the establishment was often necessary. We must particularly mention Mr. J. Dizon, the resident engineer, to whom we are indebted also for his accurate levelling of the road, and many other pieces of information obligingly communicated to us.

EXPERIMENTS ON THE QUANTITY OF FUEL CONSUMED BY THE LOCOMOTIVE ENGINES, WITH GIVEN LOADS.

Name of the Engine.	Date of the experiment.	Nature and Weight of the load, not including the tender.		Time of the trip of 29¼ miles.	Delays on the road, not included in the above time.	Average effective pressure, in lbs. per square inch.	Coke of prime quality consumed during the journey.	Coke per ton per mile on a level, help deduced on incl. plane.	Accessory Circumstances.		
									Help on the inclined plane.	Temperature of the water in the boiler.	State of the weather.
	1834.		tons.	h. m.	m.	lbs.	lbs.	lbs.			
ATLAS, from L. to M.	23 July	40 wagons .	190.00	3. 2	15	53.7	1596	0.28	Help.	Cold in the tender.	Calm.
Do. do.	9 July	25 do. . .	123.13	1.48	12	53	1102	0.34	Help.	Lukewarm in the tender.	"
Do. do.	4 Aug	25 do. . .	122.64	1.58	0	53	1224	0.34	Help.	Cold in the tender.	Fair and calm.
										The connecting rods of the wheels too tight.	
Do. do.	14 July	25 do. . .	118.90	1.31	19	61.5	1118	0.32	Help.	Cold in the tender.	Fair and calm.
Do. do.	11 July	25 do. . .	117.61	1.41	5	53	1136	0.33	Help.	Lukewarm in the tender.	"
										One piston too slack.	
Do. do.	28June	25 do. . .	113.90	1.50	5	53	1104	0.33	Help.	Rather hot in the tender.	"
Do. do.	16 July	20 do. . .	94.66	1.25	23	53.5	1081	0.39	Help.	Little lukewarm in tender.	Calm.
Do. do.	17 July	15 do. . .	65.40	1.27	3	54	1012	0·52	Help.	Very hot in the tender.	Fair and calm.
										The axle-box of one of the wagons too tight.	
Do. from M. to L.	31 July	8 loaded wagons and 4 empty	35.15	1.54	0	30	881	0.73	No help.	"	"
Do. do.	17 July	3 loaded wagons and 8 empty, and 2 wagons on a part of the road.	25.30	1.26	3	54.5	720	0.82	No help.	Very hot in the tender.	Fair and calm.
VESTA, from L. to M.	5 July	20 wagons .	92.75	1.42	5	53	916	0.33	Help.	Hot in the tender.	Calm.
Do. from M. to L.	1 Aug	5 loaded wagons and 5 empty	28.15	1. 5	0	51	774	0.80	No help.	Very hot in the tender.	Fair, moderate wind in favor of the motion.
									Engine a little stiff.	*It comes out of the repair-yard*	

EXPERIMENTS ON THE QUANTITY OF FUEL CONSUMED BY THE LOCOMOTIVE ENGINES, WITH GIVEN LOADS.

Name of the Engine.		Date of the experiment.	Nature and Weight of the load, not including the tender.		Time of the trip of 29½ miles.	Delays on the road not included in the above time.	Average effective pressure, in lbs. per square inch.	Coke of prime quality consumed during the journey.	Coke per ton per mile on a level, help deduced on incl. plane.	Accessory Circumstances.		
										Help on the inclined plane.	Temperature of the water in the boiler.	State of the weather.
		1834.		tons.	h. m.	m.	lbs.	lbs.	lbs.			
VULCAN,	from L. to M.	1 July	20 wagons . .	97.70	1.37	3	54.5	1071	0.37	Help.	Lukewarm in the tender.	Calm.
Do.	from M. to L.	22 July	9 1st cl. carriages	34.97	1.17	3	54.5	664	0.56	No help.	Cold in the tender.	Fair, very light wind against the motion.
LEEDS,	from L. to M.	15 Aug	20 wagons . .	83.44	1.35	0	54	897	0.36	Help.	Rather lukewarm in tender.	Fair and calm.
Do.	from M. to L.	15 Aug	8 do of which 1 at half way	32.01	1.17½	3	49	690	0.62	No help.	Very hot in the tender.	Fair and calm.
FURY,	from L. to M.	24 July	10 do . . .	51.16	1.30	0	60	806	0.46	No help.	Cold in the tender.	Fair and calm.
Do.	from M. to L.	24 July	10 do . . .	63.80	1.35	0	59	746	0.49	No help,	Cold in the tender.	Fair, side wind tolerably strong by intervals.
JUPITER,	from L. to M.	16 July	8 1st cl. carriages	33.09	1.12	3	53	742	0.76	Help.	Almost cold in the tender.	Fair and calm.
Do.	from M. to L.	16 July	7 do do	30.09	1.12	4	53	836	0.94	Help.	"	Fair, moderate wind contrary to the motion.
FIREFLY,	from L. to M.	26 July	8 do do	36.40	1.35	5	44	879	0.82	Help.	Almost cold in the tender. *The engine is not in a good condition.*	Fair.
Do.	from M. to L.	26 July	8 do do	36.40	1.18	5	49	870	0.81	Help.	"	Rainy, wind tolerably strong against motion.
			Sum - -	1605.65	"	"	"	20865	"		*The engine is not in a good condition.*	

In examining these experiments, we find that neither the pressure in the boiler, nor the velocity of the motion, have any remarkable influence on the result. This fact was already indicated by theory.

We also remark the advantage that is found in respect to fuel, in making the engines, whenever it is possible, draw the greatest loads their power will permit. For instance, the ATLAS, drawing a load of 25 t., consumed 720 lbs. coke, whereas, in drawing 190 t., or a load eight time as great, it only consumed double the quantity of coke. This difference must evidently, as we have explained above, be attributed to the expense of power necessary in each case, in order to overcome the resistance the coke employed was of prime quality, or *Worsley coke*, which is prepared on purpose for iron-founderies. When gas-coke is used the engines consume about 12 per cent. more without reckoning the loss resulting from the friability of that combustible. It has moreover been ascertained, that the sulphurous parts it contains are highly destructive of metals. For that reason its use has been completely given up on the Liverpool Railway, notwithstanding its low price.

In making use of coals of good quality, the quantity required is nearly the same as that of good coke; but this combustible has in regard to the preservation of the engines, the same defects as gas-coke. of the atmosphere, the engine, and its tender.

We must add, that in those experiments

Respecting the distance travelled by the engines in these experiments, the railway from Liverpool to Manchester is generally reckoned 30 miles long, and considered a level; but as a greater degree of accuracy is required in the calculation, and as we wish to deduce from these experiments the really corresponding consumption of coke on a level railway, we must reckon as follows.

One part of the line travelled by the locomotive engines is 29½ miles long. If we divide it in three parts, we see that 1 t. drawn from one end of the railway to the other, opposes the following resistances. (See the section of the railway, Chap. V. Art. VII. § 1.)

	ton.	miles.
1 t. at 26½ miles, on nearly a level - - - - - - - -	1 at	26½
1 t. at 1½ mile, ascending $\frac{1}{96}$ or $\frac{1}{89}$, equal (friction and gravity) to 4 t. drawn to the same distance on a level, or 1 t. at 6 miles - - -	1 at	6
1 t. at 1½ mile, descending by the sole force of the gravity	0	0
Sum - - -	1 at	32.5

Thus when the engines ascend the plane without help, the work they actually do is equal to the traction of a similar load to a distance of 32.5 miles on a level.

If they ascend the plane with the help of one or more other engines, their share of the load in ascending is on an average only ⅓ of the whole on the plane, and thus the work they do is equal to the traction of their load to 26.5 × 2 = 28.5 miles.

This does not include the surplus of resistance owing to the gravity of the engine and its tender in going up the plane. Their average weight being together from 13 to 14 t., the gravity of which on the plane is equal to the resistance of about 40 t. on a level, we see that this fresh effort required of the engine, equals the traction of 40 t. to a mile and a half, which is the length of the acclivity. If, therefore, the train itself weighs 30 t. without the tender, as is the case with engines that are not helped by additional ones, the work is equal to the traction of that train two miles more than the length of the line. If, on the contrary, the load weighs 60 or 80 t., as is in general the case with engines that are helped on the inclined planes, the additional traction of 40 t. for 1½ mile, is equal to the traction of the whole load to a mile.

Then for trains that receive no help at the passage of the inclined planes, we must reckon the distance for which the draft has taken place, as equal to 34½ miles *on a level;* and for the engines that are helped on the acclivity, we must reckon the work they have done as equal to the traction of their load to a distance of 29½ miles *on a level.* The difference which exists in these two cases, is of ⅛ in plus for the unassisted engines. This is the work done by the helping engines, when they are employed, and the surplus of work produced by the passage of the planes.

It is from those distances of 29.5 miles and 34.5 miles, that the numbers placed in

the eighth column of the preceding table have been deduced in each experiment.

In examining the results contained in that table, we find that they agree with the rule deduced above from the theory of the engine.

For the ATLAS, the average of the experiments made with 25 wagons, gives **119** t. conveyed by **1136** lbs. of coke. Calculating upon this data, and adding $\frac{1}{8}$ for the cases where there has been no help, we find

	tons.	lbs.	Calculation.	Experiment.
ATLAS	119 and tender	1136.		
	190 and tender		1531	1596
	95 and tender		1002	1081
	65 and tender		835	10 12
	35 and tender		779	881
	25 and tender		719	720
VESTA	93 and tender	916.		
	34 and tender		668	774
VULCAN	98 and tender	1071.		
	34 and tender		773	664
LEEDS	83 and tender	897		
	32 and tender		697	690
FURY	51 and tender	806.		
	44 and tender		759	746

If we take into account the accessory circumstances, we shall find between the calculation and the experiment, as complete a coincidence as the nature of the experiments themselves could allow; for, besides the above-mentioned circumstances, the greasing of the carriages, the quality of the coke, and, above all, the manner in which the fire-place is filled after the experiment, are subject to produce considerable differences, notwithstanding the most scrupulous attention.

The experiments we have related, give the quantity of coke consumed during the trip.

It is however clear, that in the interval between one trip and another, the engine, although at rest, continues to consume a certain quantity of fuel, because its fire must be kept up for the following journey. It is true, that several of those engines, such as the ATLAS, VESTA, and some others, have a particular sort of apparatus, by means of which, while the engine is at rest, the steam that continues to be generated in the boiler may be led to the tender. That steam is then not completely lost, being condensed in the boiler, and serving to heat the water it contains. But all the engines are not disposed in that manner.

Besides, there is in all cases consumed, every morning, a certain quantity of fuel for heating all the parts of the engine and the water of the boiler.

A surplus of consumption must therefore be calculated for those two objects. This is a practical piece of information which will find its place hereafter.

The researches contained in the work, give the solution of all such questions as are most important for the application of locomotive engines to the draft of loads on railways. They give the means of measuring the pressure of the steam; of calculating the load, the velocity, and the proportions of the engines; of valuing the different sorts of resistance they have to overcome; of taking into account the influence of additional circumstances on their motion; and, finally, of knowing their consumption of fuel.

Here naturally our work terminates. However, as a knowledge of these engines cannot be complete, unless we are able to calculate also the expenses they will require for a given draft, we add in an Appendix the necessary information, by means of which that important point may be established.

APPENDIX.

EXPENSES OF HAULAGE BY LOCOMOTIVE ENGINES ON RAILWAYS.

We have said that, in order to complete the knowledge of locomotive engines, we have still to consider them as a matter of speculation; that is to say, to examine the amount of the expenses attending the haulage by means of locomotive engines on railways. That research is the object of the present Appendix.

We shall draw the documents we have to present on that subject from the two most flourishing undertakings of the kind in England: the Liverpool and Darlington Railways. They will have, besides, the advantage of presenting examples of two very different sorts of conveyance: the one very rapid, and principally composed of passengers; the other slow, and composed of goods.

The expenses attending more especially the haulage by means of locomotive engines, are limited to the keeping in repair of the engines, the maintenance of the way, and the consumption of fuel. There are some other expenses, also, but they do not give occasion to discussion, and it will be sufficient to find their amount stated in the specified reports we subjoin at the end of this Appendix.

§ 1. *Expense for repairs of Locomotive Engines.*

In the outlays above enumerated, the expenses which must naturally first of all draw our attention, are those which attend the keeping in repair of the engines.

Before we enter into any calculations on that head, it is necessary to mention that what is meant by repairs to the engines, is nothing less than their complete re-construction; that is to say, that when an engine requires any repair, unless it be for some trifling accident, it is taken to pieces and a new one is constructed, which receives the same name as the first, and in the construction of which are made to serve all such parts of the old engine as are still capable of being used with advantage. The consequence of this is, that a re-constructed or repaired engine is literally a new one. The repairs amount thus to considerable sums, but they include also the renewal of the engines.

According to the tables at the end of this work, it will be seen that in the year ending on the 30th of June, 1834, the repairs of the engines of the Liverpool Railway cost:

From June 30, to December 31, 1833.

Materials for repairs - - -	£3,755 3 7	
Workmen - - -	4,401 4 10	
Repairs out of the establishment - - - -	613 3 9	
		£8,769 12 2

From December 31, 1833, to June 30, 1834.

Materials - -	£4,140 19 6	
Workmen - -	5,432 8 8	
		9,573 8 2
		£18,343 0 4

The question is now what was the work executed by those engines during that interval? By consulting the specified statements which will be found below, we see that the goods conveyed on that line during the year have been:

Between Liverpool and Manchester (30 miles) - - -	139,328 t.
On part of the line, making an average of 15 miles,* 24,934 t., which, on the whole, is equal to - - - - - - - - - -	12,467
Sum - -	151,795 t.

In the tables we mentioned, we find some other haulage executed, such as that for Bolton and that of coals; but this work is executed by engines which do not belong to the company, and for that reason we do not take it into account in this place.

The above-mentioned weight is that of the goods conveyed, to which must be added the weight of the wagons. Now, on that railway, the average load of a wagon is 3.5 t., and the wagon itself weighs 1.5 t.; so the weight of the carriages that served for the above mentioned tonnage will be known by multiplying the number obtained, by the ratio $\frac{1.5}{3.5}$. And as, moreover, the engines, for want of sufficient returning traffic, are obliged to bring back half the wagons empty

*The distance to which the company carries the Wigan and Warrington trade, which make the principal part of this article, is 15 miles.

in one of the two directions, or $\frac{1}{4}$ of the whole, we shall have for the *gross weight* drawn by the engines in the course of the year—

Weight of the goods - -	151,795 t.
Weight of the corresponding wagons - - - -	65,055
Weight of the wagons brought back empty - - -	16,264
	233,114 t.

This is the tonnage of the goods, to which must be added that of the travellers. In the course of the year, 415,747 travellers were conveyed from one city to the other in 6570 journeys.* This makes an average of 64 travellers pet train. The coaches required for that number of travellers, including the empty carriages added to each train to be ready for any emergency, are six carriages of the first class, or five of the second.†

The weight of six first class coaches, including the mail, is - -	21 t.
The weight of a second class train of five carriages, including one glass coach, is - - - -	12.6

Lastly, for 13 trains of the first class there are 16 of the second. Thus the average weight of the carriages for every 64 travellers may be reckoned at 16.4 t.

Consequently, the total weight corresponding to the travellers conveyed was:

415,747 travellers at 15 per t. -	27,717 t.
Corresponding weight of the carriages - - - -	107,748
Luggage of the travellers, at 28 lbs. each - - - -	5,197
	140,662 t.

Thus the total definite weight, drawn by the engines belonging to the company during the year was—

Gross weight for goods -	233,114 t.
Gross weight for travellers -	140,662
	373,776 t.

We have already shown in this work (Chap. IX. § 2) that, taking into account the surplus of resistance occasioned by the gravity at the passage of the inclined planes of that line, the load must be considered as carried to a distance of 34 miles and a half on a level. Thus as a ton carried to a distance of 34.5 miles is equal to 34.5 t. carried to a distance of one mile, the draft here above it equal to 12,895,272 gross tons carried to one mile on a level.

For that haulage the repairs of the engines cost £18,343 0s. 4d., consequently the repairs, per gross ton carried to one mile on a level, amounted to

0.342*d*.

In order to execute this haulage, the engines made 6570 journeys drawing stage-coaches, that is to say, with a velocity of 20 miles an hour; and 5086 journeys, with goods, or with a velocity of 12.5 miles an hour. The average velocity of the haulage, was consequently, in miles per hour, 16.73 miles.

We have said elsewhere that the Liverpool and Manchester Railway Company possesses at present thirty locomotive engines. It must not be concluded, however, that that number is necessary in order to execute the above said haulage. Of these 30 engines about one-third are useless. They are the most ancient which, having been constructed at the first establishment of the railway, at a time when the company had not yet obtained sufficient experience in that respect, are found now to be out of proportion with the work required of them.

The engines actually in daily activity on the road amount to about 10 or 11, and with an equal number in repair or in reserve the business might completely be ensured. This is in fact what happens at present, the surplus, above that number, being nearly abandoned.

We shall complete we have just been saying on the Liverpool locomotive engines, by adding a document that will show what these engines are capable of executing in a daily work, and the improvement they have undergone in the course of the last few years, in respect to the solidity of their construction.

* This is the number of the travellers inscribed in the company's books. It includes neither the travellers put down nor those taken up on the road, the numbers of which balance each other.

† The first class carriages are glass coaches, containing each 18 persons; they weigh 3.65 t. Those of the second class are open, and have 24 places; their weight is 2.23 t. Lastly, the mail-coaches weigh 2.71 t., and carry 10 travellers. Each glass coach has besides one outside place.

WORK DONE BY THE TEN BEST ENGINES OF THE LIVERPOOL AND MANCHESTER RIALWAY, DURING THE YEARS 1831, 1832, 1833, AND THE TWELVE FIRST WEEKS OF 1834.

Year.	Name of the Engine.	Totaldistance travelled by the Engine.	Total time the engine has been on the road, either in activity or in repair.
		Miles.	Weeks.
1831.	MERCURY -	23,212	52
	JUPITER -	22,528	44
	PLANET - -	20,404	52
	SATURN -	19,510	38
	MARS - -	18,645	50
	MAJESTIC -	18,253	52
	NORTH STAR	15,677	52
	NORTHUMBR'N	15,607	52
	PHŒNIX -	15,405	52
	SUN - -	13,434	37
	Sum - -	182,675	481
	Av. per week	380	
1832.	VULCAN -	26,053	52
	LIVER - -	22,651	43
	VENUS - -	20,464	52
	ETNA - -	20,399	52
	SATURN -	20,312	52
	VESTA - -	17,739	52
	VICTORY -	17,082	52
	PLANET -	16,885	52
	SUN - -	16,535	52
	FURY - -	15,603	52
	Sum - -	193,723	511
	Av. per week	379	
1833.	JUPITER -	31,582	52
	AJAX - -	26,163	52
	FIREFLY -	24,879	39
	LIVER - -	23,134	52
	PLUTO - -	20,308	52
	VESTA - -	19,838	52
	LEEDS - -	19,364	48
	SATURN -	18,738	52
	VENUS - -	18,348	52
	ETNA - -	17,763	52
	Sum - -	220,117	503
	Av. per week	438	
1834.	FIREFLY -	8,542	12
	VULCAN -	8,526	12
	SATURN -	7,290	12
	LIVER - -	7,080	12
	SUN - - -	7,080	12
	ETNA - -	6,557	12
	LEEDS - -	5,712	12
	AJAX - -	4,890	12
	VENUS - -	4,632	12
	PLUTO - -	4,246	12
	Sum - -	64,555	120
	Av. per week	538	

Among those engines, the *Liver* had worked for 107 weeks, had travelled 52,865 miles, or, on an average 494 miles a-week during all that time; the *Firefly* had worked 57 weeks, had travelled a distance 33,421 miles, or 586 miles per week, and neither of these engines at the period in question, had yet required a fundamental repair.*

This statement shows what can be expected from locomotive engines, when constructed with care and of good materials; and there is no doubt that, in time, more work will still be obtained from them.

—

In order to give also an instance of the expense of repairs of locomotive engines, under other circumstances, and with another mode of construction of the engines, we shall set down here the work performed by the locomotive engines on the Darlington Railway, during the same year, that is to say, from June 30, 1833, to June 30, 1834, and the amount of expenses for repairing those engines for the same space of time.

On this Railway the number of trips of 20 miles, down hill, performed in the course of the year, was 5318½. In each of these journeys the engine had to draw, in coals, a load of 63.6 t., which puts the total work at 6,764,951 t. carried to the distance of one mile.

But as this tonnage does not include the tare of wagons, and as, independently of this descending trade, it is also necessary to bring the empty wagons *up* the line again, this point requires our entering into some particulars, in order to be able to deduce from it the work really executed by the engines.

We shall elucidate it before we go any farther.

When a weight of one ton is drawn on a level Railway, we have seen that it requires a traction of 8 lbs. But if the line is not all on a level, upon each *ascending* plane, the gravity of the mass drawn will be an additional resistance to be overcome, and must consequently be added to the 8 lbs. traction, already necessary in order to overcome the friction of the wagons. For the contrary reason, in the *descending* planes that gravity enters into deduction of the power to be exerted, and must consequently be substracted instead of added.

* The greater part of these excellent engines were built by R. Stephenson, so well known for his important and numerous improvements in this branch of industry.

The *Liver* engine, the merit of which is sufficiently established by the above stated facts, is the work of Messrs. Edward Bury and Kennedie, of Liverpool.

If, however, the same train, after having ascended an inclined plane, descends another equal one, the addition in one case being exactly equal to the substraction in the other, the consequence will be, that the definitive resistance of a ton will remain the same as if the way had been level.

Or, if the way has a known average inclination, from which it deviates, at times augmenting and at others diminishing, returning, however, always to that average inclination, the same principle of compensation will stand good still, and it will be sufficient to calculate the traction required on that average inclination.

But this principle which has its foundation in the supposition that the engine is just as much eased in one point as it is overcharged in another, ceases to be true on all such planes where the gravity surpasses the friction; that is to say, on all planes where the inclination is greater than $\frac{1}{280}$. In fact, beyond that point the overcharging in ascending continues to augment rapidly, while the load in going down, already reduced to nothing on a plane at $\frac{1}{26}$, cannot diminish any more. All compensation therefore ceases.

This remark proves that the consideration of the gravity, on the average inclination of a line, gives the real resistance on that line, only in case it contains no *descending* planes of a greater inclination than $\frac{1}{280}$, or in case those that are in that predicament have been reckoned separately.

Applying that principle to the Darlington Railway we find, according to the section of that line*, that on its total length there are eight inclined planes on which the gravity surpasses the friction. The length of these eight planes being together 10.23 miles, which is a half of the whole distance, we see that, during one half of their journey in descending, the Darlington engines have no traction to exercise, and that the trains go down of themselves. The remaining half of way, being practically level ($22\frac{1}{2}$ feet in descent for $10\frac{1}{2}$ miles,) the engines have on that part the traction of a level line, that is to say, 8 lbs. per ton. So their average traction during the whole descent is 4 lbs. per ton, or in other words, their work is equal to the draft of their load to half the distance on a level. We see here how great a mistake we would have made if we had taken as a rule the *average* inclination of the whole line; for that inclination being $\frac{1}{288}$, we would naturally have concluded that for all the descending trade, the traction was almost reduced to nothing.

Coming back, therefore, to the tonnage on the line, we have seen that it amounts, for the *goods*, to

6,764,951 t.

This number does not include the weight of the wagons themselves. These wagons weighing 1.30 t., and their load being 2.65 t., the addition to be made on that account, will be found in multiplying the above number by the ratio $\frac{1.30}{2.65}$.

Thus the total weight carried in *going down* the line is

Weight of the coals	6,764,951 t.
Weight of the wagon	3,318,656.
Total wt. drawn to a distance of one mile descending	10,083,607 gr. tons.

We have seen that the draft of one ton to the distance of one mile, in going down the line, is equal to the draft of the same load to the distance of half-a-mile *on a level.* The above-mentioned tonnage referred to a

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* The part of that Railway travelled by the locomotive engines begins at the foot of Brusselton inclined plane, at an elevation of 383 ft. 1 in. above the quay at Stockton, where it terminates, after passing over the following inclinations:

Miles.			
0.46	- -	descent.	at $\frac{1}{311}$
0.06	- -	do.	- $\frac{1}{325}$
0 92	- -	do.	- $\frac{1}{144}$
1.45	- -	do.	- $\frac{1}{121}$
2.25	- -	do.	- $\frac{1}{528}$
1.25	- -	do.	- $\frac{1}{135}$
1.01	- -	do.	- $\frac{1}{352}$
1.76	- -	do.	- $\frac{1}{135}$
0.20	- -	do.	- $\frac{1}{308}$
1.75	- -	do.	- $\frac{1}{1584}$
1.61	- -	do.	- $\frac{1}{1408}$
1.64	- -	do.	- $\frac{1}{204}$
0.23	- -	do.	- $\frac{1}{713}$
2.09	- -	do.	- $\frac{1}{2192}$
1.25	- -	do.	- $\frac{1}{253}$
0.03	-	leve	-
0.81	- -	descent.	- $\frac{1}{226}$
0.05	- -	do.	- $\frac{1}{487}$
0.80	- -	do.	- $\frac{1}{1584}$
1.16	- -	do.	- $\frac{1}{104}$

Sum 20.78. Average inclination, 383 feet on 109,692 feet, or $\frac{1}{288}$.

Besides the principal line, there are lateral branches over which the locomotive engines also travel, but the level of which has not been taken. The aggregate space travelled over by the locomotive engines is 24 miles. The rest of the Railway consisting of 16 miles more, is worked by horses and by stationary steam engines.

level, represents consequently 5,041,803 gross tons carried to a distance of a mile.

In order to estimate the draft in *going up*, we may retain or not the division of the line in two parts, the result is the same; but the simplest way is to make use of the average inclination at $\frac{1}{280}$. The calculation we have to make regarding only the *ascending* line, which contains no descending plane, and *a fortiori*, no descending plane of a greater inclination than $\frac{1}{280}$, the division established above is no longer necessary.

Considering, then, that the ascending trains are composed of 24 empty wagons, weighing together 31.2 t.; that, besides, on the inclined planes, the gravity of the engine and its tenders offers an additional resistance which would not take place on a level; finally, that the weight of the engine is 10 to 11 t., and that two of the tenders, half empty, 4.5 t.; which makes in all, on the inclined plane, a mass of 46.2 t., to be moved; it will be seen that the total resistance opposed by the steam, is,

Friction of the wagons, 31.2 t. at 8 lbs. per ton - - -	249.6 lbs.
Gravity of the mass 46.2 t. on an inclined plane at $\frac{1}{280}$.	362
Total resistance,	611.6 lbs.

This, being the resistance that results from a train composed of 31.2 t. makes per ton 19.60 lbs., or in round numbers, 20 lbs. As we know, on the other hand, that on a level one ton requires only 8 lbs. traction, we see that the necessary force is here twice and a-half as great; or in other words, we see that the draft of one ton to a distance of one mile, *going up* that line, is equal to that of the same load to 2.5 miles *on a level*.

This granted, we have found that the haulage of the wagons is equal to 3,318,656 tons conveyed to the distance of one mile in going up. Referring this to a level, it will be represented by the same number multiplied by 2.6, that is to say, it will be 8,296.640 gr. t. carried to a distance of one mile on a level.

From which follows, finally, that the total work executed by these engines and referred to a level, is,

Draft in going down, in gross tons carried to a distance of one mile on a level . . .	5,041,803 t.
Draft in going up, measured in the same way	8,296,640
Sum . . .	13,338,443 t.

The number of tons of coals which produced this draft being, as we have seen, 6,764,951 t., we find that, on account of the weight of the necessary wagons and the difficulty of the draft in going up, the haulage of those six millions and a-half of *goods* produced really a draft equal to thirteen millions of tons on a level; that is to say, to be more accurate, that in comparing these two numbers, we see that the real work executed by the engines may be deduced from the weight of the goods by multiplying the latter number by 1.9718.

This first point established, we may now come to the amount of the expenses of repairs.

After having for a long while kept and repaired their engines themselves, the Directors of the Darlington Company decided, in order to avoid minute accounts, to enter into a contract for that; and, in consequence, in 1833, they put their engines in the hands of three persons.

By the contract entered into, and which is at present in force, the company pays $\frac{4}{10}$ of a penny per ton of *goods*, carried to a distance of one mile; and, for that price, the contractors have undertaken, not only to keep the engines in good repair, furnishing workmen and materials, but also to pay all the current expenses of haulage, such as salary of the engine men, fuel, oil, grease, &c. Besides this, they must also pay the company an interest of five per cent. on the capital representing the value of the engines, and of all the establishments placed at their disposal for working.

The total sum paid to the contractors by the company for that object during the year ending June 30, 1834, was

£11,347 1*s.* 9*d.*

And deducting the expenses for rent, interest of capital and haulage, the amount of which is known, the directors of the company reckon that the definitive sum remaining with the contractors for the repairs of the engines (bars of the fire-box included,) amount, with the general profit on the whole undertaking, to

£5,732 18*s.* 5*d.*

This sum has been expended for the carriage of 13,338,443 gross tons to a distance of one mile on a level; so that finally the expense, per gross ton carried to one mile on a level, including the profits on the undertaking amont to

0.103*d.*

As a complement to what we have said, and to show on this railway as well as upon the Liverpool one, the work the engines are able to perform, we shall give a table of the haulage executed, and repairs undergone by the engines during the last five last months of the year 1833.

STATEMENT OF THE WORK DONE BY THE LOCOMOTIVE ENGINES ON THE DARLINGTON RAILWAY, FROM JULY 1, TO DECEMBER 1, 1833.

Number of the engine.	Name of the engine.	Total number of miles travelled by the engine.	Tons of coals carried to one mile going down by the engine.	Gross tons carried to one mile on a level including the wagons and return.	Number of days that the engine was: In activity.	Number of days that the engine was: In repair.	Amount of the repairs made to the engine during that time. £	s.	d.	Amount of the repairs per gross ton carried to 1 mile on a level.	Observations.
		miles.	tons.	tons.	days.	days.	£	s.	d.	d.	
1	Locomotion	5,300	146,041	287,896	80	52	41	19	7	0.035	Boiler with a flue and two returning tubes.
2	Hope	3,100	82,305	162,281	66	69	57	5	5	0.085	" with a single flue.
3	Black Diamond	1,000	26,920	53,078	27	105	14	0	5	0.063	" with a singlle flue.
4	Diligence	80	1,906	3,758	2	130	13	18	3	0.889	Engine taken to pieces.
5	Royal George	700	23,733	46,794	11	121	161	7	8	0.828	Boiler with a flue and one returning tube.
6	Experiment	4,400	122,442	241,420	70	62	53	1	2	0.053	ditto
7	Rocket	3,940	109,512	215,925	64	68	57	0	9	0.063	ditto
8	Victory	10,600	349,150	688,418	107	25	58	3	10	0.020	ditto
9	Globe	3,120	70,682	139,365	60	72	36	4	6	0.062	Boiler with 120 returning tubes.
10	Planet	1,200	20,429	40,280	27	105	53	7	5	0.318	" with 88 "
11	North Star	2,400	47,546	93,746	55	77	32	5	10	0.083	" with 88 "
12	Majestic	2,880	90,422	178,282	47	85	131	2	3	0.177	" with 104 "
13	Coronation	2,940	97,687	192,609	52	80	46	16	2	0.058	" with 104 "
14	William IV.	4,060	134,540	265,075	55	77	78	19	8	0.072	" with 104 "
15	Northumbrian	4,480	143,885	283,698	59	73	67	14	11	0.057	" with 104 "
16	Director	5,860	202,492	399,253	91	41	107	19	11	0.065	Boiler with tubes on the model of Napier's patent.
17	Lord Brougham	4,780	155,729	307,051	62	70	62	5	10	0.049	Boiler with 104 returning tubes.
18	Shildon	4,720	159,400	314,289	63	22	49	16	3	0.038	" with a flue and two returning tubes.
19	Darlington	6,180	209,110	394,559	88	44	45	0	6	0.027	" with a flue and two returning tubes.
20	Adelaide	3,700	126,390	249,202	71	61	90	11	7	0.087	" with 104 returning tubes.
21	Earl Grey	7,960	276,462	545,088	110	22	14	19	6	0 007	" with a flue and two returning tubes.
22	Lord Durham	6,480	213,737	421,424	84	48	67	13	8	0.039	" with 104 returning tubes.
23	Wilberforce	4,200	141,534	279,062	55	9	51	17	11	0.045	" with 104 "
	Sums	94,080	2,942,925	5,802,562	1403	1518	1393	13	0	0.058	

The greatest part of the machines were constructed by Mr. Timothy Hackworth, of Shildon, near Darlington, and bear testimony to his skill. Twelve of them were almost new at the time this statement was made.

§ 2. *Expense for Maintenance of Way.*

The expenses for keeping the Liverpool Railway in repair, during the year we are considering, are given in the reports that will be found below. From the sums put down must be deducted the articles *ballast* and *new rails*, the first being caused by the recent construction of the road, that is to say, by the gradual sinking of the embankments, which are not completely compact, and the second being an extraordinary replacing of the rails on a part of the line.

Putting, therefore, those two articles aside, the expenses for repairing the railway, during the year ending on the 1st of June, 1834, were

£11,053 2*s*. 6*d*.

During the same time, the loads that passed on the railway drawn either by the company's engines, or by engines belonging to other companies, were

Goods on the whole road	139,328 t.	
—— on the half of the road 24,934 t., making on the whole line . .	12,467	
—— between Bolton and Manchester or Liverpool 38,-341 t., or on the whole road . .	19,170	
Coals on the half of the line 86,173, or on the whole . .	43,086	
		214,051 t.

Correspoding wagons ($\frac{1.5}{3.5}$ of the weight of the goods) . . .	128,431
Wagons brought back empty (¼ of the whole)	32,108
Carriages, and passengers' luggage, as above	140,662
Sum . .	515,252 t.

Thus 515,252 gr. t. passed on each mile of the railway, having amounted to £11,-053 2*s*. 6*d*., or to £368 8*s*. 1*d*. per mile, the expense per mile for each ton carried was

0.171*d*.

In this calculation we have only taken the *useful* length of the railway; that is to say, that we have omitted the sidings, &c., they being only the necessary complement of the principal line.

On the Darlington line, during the same year, the expenses for repairs on the 24 miles run over by the *locomotive* engines, were

Workmen . .	£4,253 0 0
Materials . . .	2,060 0 0
	£6,313 0 0*

The weight that passed during the same time, on that part of the railway, was:

Coals, 6,764,951 tons carried to distance of one mile, or upon the whole of the 24 miles	281,873 t.
Corresponding wagons ($\frac{1.30}{2.65}$ of the weight of the goods)	138,277
Wagons going up the line (same weight)	138,277
	558,427 t.†

The expenses for the whole of these 24 miles amounting to £263 0*s*. 10*d*. Thus the expenses for maintenance of way, per mile, and for each gross ton conveyed on the road, were

0.113*d*.

We have here also, as well as above, left out the crossings, sidings, &c.

This amount would undoubtedly be diminished if the Darlington wagons were

* The total expense for repairs of the line, during the year we are considering, were

Workmen	For the 24 miles run over by the locomotive engines . .	£4,253 0 0
	For the 16 miles worked by horses or stationary engines	1,067 5 0
Materials for repairs	Space run over by the locomotive engines . .	2,060 0 0
	Parts worked by horses or stationary engines	518 3 8
Repairs to bridges . . .		69 17 7
Repairs to walls and fences .		280 7 11
Accidental expenses . .		467 3 7
Total expenses .		£8,715 17 9

N. B. The distinction between the expenses relating to the space run over by locomotive engines and by horses, could only be made by approximation; as the company does not keep separate accounts in that respect.

† Besides this weight, there passes on the line a small number of stage coaches, which for the last few months have been drawn by locomotive engines. But this haulage being inconsiderable, we did not wish to embarrass our calculation with it.

on springs, like those of the Liverpool Railway.

These expenses, as we have seen, amount only to the two-thirds of those of the Liverpool Railway for the same object. The difference is owing to the rapid motion of the engines and carriages that pass on the latter railway. But it is chiefly in the expense for repairs of engines that this effect of velocity is felt.

It must not, however, be supposed that the considerable difference observed in that respect, between the engines of the two companies, is exclusively owing to the velocity of the motion. That velocity enters, indeed, for a great part in it, but the conditions attending each sort of business have a no less considerable influence on it. What we mean is, that passengers forming the chief business on the Liverpool line, their safety requires that a much greater care be taken of the engines than when the load is composed only of coals, as on the Darlington Railway. The consequence is, that the Liverpool engines are kept with a degree of care, we might even say of luxury, to which the Darlington ones can by no means be compared. In order to explain completely our idea, we shall say that the business of the Darlington Railway is a business of wagonage, and that of the Liverpool Railway a business of stage coaches.

The *data* laid down above must therefore be taken each in their speciality, that is to say, the one as suitable to a slow motion, with engines of a certain construction and intended for the draft of goods, and the other to a rapid motion with engines of a different construction, and intended for the draft of passengers.

Before we close this article, we must remark that the repairs of the railway consist principally in replacing the blocks, chairs, keys, and pins. The rails themselves, being in malleable iron, seldom break. As for their gradual decrease of weight, by wear, this is a very inconsiderable effect.

On May 10th, 1831, on the Liverpool line, a malleable iron rail, 15 feet long, carefully cleaned, weighed 177 lbs. 10½ oz. On February 10th, 1833, the same rail, taken up by Mr. J. Locke, then resident engineer on the line, and well cleaned as before, weighed 176 lbs. 8 oz. It had consequently lost in 21 months a weight of 18½ oz. The number of gross tons that had passed on the rail during that time was estimated at 600,000. Thus we see that with so considerable a tonnage, and with the velocity of the motion on that railway, the annual loss of the rail was only $\frac{1}{268}$ of its primitive weight. So that it would require more than a hundred years to reduce it to the half of its present strength.

§ 3. *Expense of Fuel.*

In regard to fuel, we have already, in Chapter IX. of this work, related experiments from which may be deduced the consumption of fuel according to the load the engines have to draw.

However, as in the intervals of the trips the fire must be kept up, and as, besides, there are always unavoidable losses during working, an increase of expense in that respect must naturally be expected in practice. This we also learn in a positive manner by the examination of facts.

According to the half-yearly reports of the Liverpool Railway Company, for the year ending June 30, 1834, the expense for fuel for the locomotive engines was

£6,079 15*s.* 8*d.*

The number of trips performed was 11,656; consequently the expense for fuel for each journey amounted to 10.432*s.*, and as the average price of coke employed during that year on the railway was 23.5s., the consumption of fuel, measured in weight, amounted to 994.37 lbs. per trip.

We have seen (Appendix, § 1.) that the total number of gross tons conveyed by the locomotive engines of the company from one end of the railway to the other, in the same number of journeys was

373,776 t.

The average load of the engines was consequently about 32 tons.

A load of 32 tons, not including the tender, has consequently required, by the fact, a consumption of coke of 994 lbs. So, considering that the load has been really carried to a distance of 34½ miles, this makes 0.90 lbs. per gross ton drawn to a distance of one mile on a level. Our special Experiments (Chap. IX. § 2.) only give an average consumption of 784 lbs. of coke for a load of 32 t. By this it will be seen that, in practice, and with the nature of the business on that line, the different losses amount to one-fourth of the expense of the active work.

This increase is owing not only to the necessary expense for lighting the fire every morning, but also to the necessity, on that line, of keeping, for the passage of the inclined planes, helping engines, the fire of which must remain lit the whole day, although they only serve at distant intervals, and to the long delays between one journey and another. These circumstances, that of the helping engines alone excepted, are inevitable in a business of the nature of that of Liverpool.

On the Darlington Railway the same causes of loss do not exist, at least not to the same degree.

According to the notes, carefully kept by the directors of that company to serve as a

foundation to the contracts they sign, the quantity of coals consumed on an average, during one journey of an engine, that is to say, to convey 24 wagons to a distance of 30 miles down hill, and bring them back again empty to the same distance up hill, costs the engine men 4*s.* 9¾*d.*, when the coals are at 5*s.* per ton. So the weight of coals consumed is 2157 lbs.

The *useful* load drawn by the engine is composed of 63.60 t. of coals in going down, and there is no *useful* load at all in going up; making an average of 31.80 tons of goods drawn to a distance of 40 miles in all.

This weight, from what we have seen (Appendix, § 1.,) corresponds with a *gross* weight, drawn on a level to the same distance, of

$$31.80 \text{ t.} \times 1.9717 = 62.70 \text{ t.};$$

the consumption of coals per gross ton carried to a distance of one mile on a level is, consequently, 0.86 lb.

This is nearly the same consumption as on the Liverpool Railway, especially if we consider that a ton of coals, of a good quality, produces a little more evaporation than the same weight of good coke.*

This result may appear surprising, the boilers of the Darlington engines being generally constructed on a less economical principle, as to the application of heat, than the Liverpool ones; but considering the way of working on each line, this circumstance will easily be accounted for. On the Darlington Railway the engines never go off but with a full load; that is to say, that they draw, as we have mentioned, an average weight of 62.7 t. per trip, and we know that this circumstance is favorable to the consumption of fuel. If these engines were to draw only an aveage load of 32 t., like the Liverpool ones, their comparative consumption would certainly be greater. To this must also be added that, on the Darlington Railway, the engines undergo no delay between their journeys, and that the invariability in the load and in the speed makes it unnecessary to give them more evaporating power than is strictly wanted for their motion. The consequence is that one never sees at the valve that enormous blowing which takes away from the Liverpool locomotive engines a fourth part of their produce.

It is to these combined circumstances that the practical result appearing in this case, must be attributed.

* The proportion of the quantity of coke prepared in a closed vessel, and of Newcastle coals, necessary to transform the same quantity of water into steam at the same pressure, is nearly as 14 to 13.

§ 4. *Total Expense of Haulage.*

The remaining expenses of the haulage require, on our part, no separate discussion. The particulars will be found in the following statements relating to the Liverpool Company. But their aggregate amount acquaints us with the total expense of haulage by means of locomotive engines, and this is a point which requires some consideration as well as the former ones.

According to the statements concerning the year in question, we see that the total expenses of the Liverpool Company amounted to the following sums:

	£	s.	d.
1st half-year . . .	56,350	1	9
2nd half-year . . .	60,092	15	11
	£116,442	17	8

But our purpose being to know the expenses relating to the use of the locomotive engines taken separately, in order to compare the amount with the total haulage they executed, we must deduct from that sum the following articles:

	£	s.	d.
1st. Interest on loans 1st hlaf-year	5,140	6	4
2nd half-year	5,546	4	0
2nd. Stationary engine and tunnel disbursements 1st half-year	1,307	16	5
2nd half-year	986	10	3
3rd. New rails, this being an extraordinary expense 1st half-year	150	16	0
2nd half-year	3,153	14	0
4th. From the amount for maintenance of way, new rails not included, must be deducted $\frac{1}{10}$ for expenses concerning the tunnels, that are not worked by the locomotive engines and the length of which is 1½ mile on the 31 miles of the whole line 1st half-year	627	10	0
2nd half-year	619	14	0

5th. On the rest of the expense for maintenance of way must also be deducted $\frac{3}{5}$, being expenses occasioned by the passage, with their trains, of locomotive engines not belonging to the company. The haulage effected by the engines of the company being 373,776 tons, carried on the whole line. We have seen (Appendix, § 2) that the work of the engines not belonging to the com-

pany, raises the tonnage to 515,252 tons; consequently the work of the latter engines is 141,476 tons, or $\frac{2}{7}$ of the haulage of the company's engines.

This article makes

	1st half-year	2 258	18	0
	2nd half-year	2,231	0	0
Total sum to be deducted		£22,022	9	
Remains for expenses concerning the work of the company's locomotive engines		94,420	8	0

The haulage executed by the same engines being

12,895,272 gross tons carried to a distance of one mile,

the consequence is that, on the Liverpool Railway, at an average velocity of 16.73 miles per hour, the total expense of haulage by locomotive engines amounts to

1.75 d. *per gross ton carried to a distance of one mile on a level.*

This includes all sorts of expenses, carriages, rent, offices, &c.

On the Darlington Railway the expenses of haulage are much lower. The company estimates them at 1.00 d. *per ton of coals* carried to one mile *in going down* the line; which, after our calculation (Appendix, § 1.,) would make 0.51 d. per *gross* ton carried to one mile *on a level.*

The cause of that difference between the two railways has already been mentioned, being the velocity of the motion and the nature of the goods conveyed. To this must also be added the considerable difference in the price of fuel, the Darlington Company employing coals which cost only 5s. per ton, instead of 23s. 6d., the price of the coke used by the Liverpool Company. But the use on that line of several ways of working either by locomotive or stationary engines, or by horses, does not permit us to class and verify the expenses with the same precision as in the case of Liverpool. This is the reason why we shall not enter into any particulars in that respect.

§ 5. *Profits.*

After having examined the expenses, it is also necessary to cast a look on the receipts. Before we go over to the specified statements of the expenses of all sorts of the Liverpool Company, we shall therefore take down here, from those same statements the amount of the profits made by the company from the opening of the railway. This sketch will show that, if the mode of haulage in question necessitates considerable expenses for its establishment, the profits it produces are fully adequate to indemnify speedily the shareholders.

The road was opened to trade on September 16th, 1830, and from that period the dividends per share of £100 sterling amounted to the following sums:

December 31, 1830 - - -	£2	0	0
June 30, 1831 - - - - -	4	10	0
December 31, 1831 - - -	4	17	8
June 30, 1832 - - - - -	4	4	8
December 31, 1832 - - -	4	8	0
June 30, 1833 - - - - -	4	7	6
December, 31, 1833 (besides a reserved fund of 4,088 8s. 10d.) - - - - - - -	4	15	3
June 30, 1834 - - - - -	4	15	2
Total Sum from Sep. 16, 1830, to June 30, 1834, that is to say, in three years, nine months and a-half - -	£33	18	3

This sum makes 9 per cent. a-year, besides the reserved fund laid aside by the company, and notwithstanding the extraordinary expenses inevitable at the beginning of an undertaking, which being the first of its kind, was necessarily obliged to pay dearly for its own experience, whilst future railways will profit by that acquired by their predecessors.

Besides this high interest for the capital invested, we repeat that the shares of this railway, from the original price of £100 sterling, have risen, and sell at present, after four years establishment only, at £210; and that those of the Darlington Railroad, which boasts only nine years' existence, give 8 per cent. interest, and have risen in that short interval from £100 to £300, which is their present price.

This plain recital of facts speaks volumes. It is, therefore, unnecessary for us to add any reflection.

We shall be happy if the elucidations we have already given and those we intend to subjoin be of use to persons who may feel inclined to engage in these speculations, which, in regard to expenses, cannot fail to be as advantageous to their private fortune as to the prosperity of the country at large.

We shall conclude this Appendix by giving the specified statements of the receipts and expenditure of the Liverpool Company, from its origin to the present moment.

EXTRACTS

FROM THE REPORTS OF THE DIRECTORS OF THE LIVERPOOL AND MANCHESTER RAILWAY, FROM THE OPENING OF THE RAILWAY, ON THE 16TH SEPTEMBER, TO THE 30TH JUNE, 1834.

STATEMENT OF EXPENDITURE ON CAPITAL ACCOUNT.

Amount of expenditure on the construction of the way and the works, from the commencement of the undertaking to 31st December, 1833 - - - £1,089,818 17 7

ANNUAL OR WORKING ACCOUNT.

FROM 16TH SEPTEMBER TO 31ST DECEMBER, 1830.

Nett profits of the Company	£14,432	19	5
Dividend per share of £100	2	0	0

HALF-YEAR ENDING 30TH JUNE, 1831.

Nett profits of the Company	£30,314	9	10
Dividend per share of £100	4	10	0

HALF-YEAR ENDING 31ST DECEMBER, 1831.

	Tons.
Merchandise between Liverpool and Manchester	52,224
Road traffic - - - - -	2,347
Between Liverpool and the Bolton junction - - - - -	10,917
Coal from Huyton, Eltonhead, and Haydock collieries brought by the Company's engines - -	7,198
Coal from Hulton brought by the Bolton engines - - -	1,198
Number of passengers booked at the Company's offices - - -	256,321
Number of trips of 30 miles performed by the locomotive engines with passengers - - -	2,944
Do. with goods - - - -	2,298
Do. with coal - - - -	150

Receipts.

Coach department -	£58.348	10	0
General merchandise -	30,764	17	8
Coal department - -	605	14	5
	£89,809	2	0

Expenses.

Office establishment -	£902	3	10
Coal disbursements -	60	15	5
Petty ditto - - -	110	0	5
Cart ditto - - -	60	17	8
Maintenance of way -	6,599	12	6
Charge for direction -	297	19	0
Coach office establishment	589	5	9
Locomotive power -	12,203	5	6
Advertising - - -	59	3	4
Interest - - - -	2,737	7	3
Rent - - - -	900	5	3
Compensation (coaching department) - - -	156	7	5
Engineering department	625	0	0
Carrying disbursements	10,450	12	3
Taxes and rates - -	2,763	5	1
Stationary engine disbursements - - - -	269	4	7
Coach disbursements -	6,709	7	11
Wagon ditto - - -	979	19	8
Compensation (carrying department) - - -	786	8	2
Police establishment -	1,490	14	1
Law disbursements -	98	9	10
Bad debts - - -	175	13	6
	£49,025	18	5

Nett profit from 1st July to 31st Dec. 1831 - -	£40.783	3	7
Dividend per share of £100	4	10	0
Nett profit on Sunday travelling per share of £100	0	7	8

HALF-YEAR ENDING 30TH JUNE, 1832.

	Tons.
Merchandise between Liverpool and Manchester - - -	54,174
Traffic to and from different parts of the road - - -	3,707
Between Liverpool and the Bolton junction - - -	14,720
Coals from different parts of the road brought by the Company's engines - - -	22,045
Coals brought by the Bolton engines . . .	7,411
Number of passengers booked at the Company's offices .	174,122
Number of trips of 30 miles performed by locomotive engines with passengers . .	2,636
Ditto with merchandise .	2,248
Ditto with coals . .	234

Receipts.

Coaching department .	£40,044	14	7

General merchandise department . . .	32.477 14 0
Coal do	2,184 7 6
	£74,706 16 1

Expenses.

Bad debt account .	394 5 7
Coach disbursements. Guards' and porters wages, £1104 4 6—Parcel carts and drivers' wages, £254 10 5—Omnibuses and duty, £1082 0 7—Repairs and materials, £1777 9 4—Gas, oil, tallow, &c. £223 14 6—Stationery and sundry disbursements, £441 1 7	4888 0 11
Carrying disbursem'ts. Salaries £1749 5 10—Porters' wages £3862 0 8—Brakesmen's wages £461 5 9—Oil, tallow, cordage &c. £561 12 6—Carting £808 16 5—Repairs to jiggers, trucks, &c. £163 14 11—Stationery and sundry expenses, £563 10 8	8010 6 9
Coal ditto . . .	26 8 10
Cariage (Manchester) .	1420 4 9
Charge for direction .	308 14 0
Compensation (coaching) .	101 10 9
Compensation (carrying) .	288 10 3
Coach office establishment (salaries, £573 13 1—Rent and taxes, £106 10 0.)	680 3 1
Engineering department .	520 9 0
Interest	5966 14 11
Locomotive Power. Fuel and watering £2907 8 0—Oil, tallow, hemp, &c. £507 3 1—Repairs and materials £5947 6 5—Enginemen's wages £1170 18 8	10,582 16 2
Maintenance of way (wages, £3929 8 0—Blocks, sleepers, chairs, &c. £2668 12 3—Ballast, £733 0 3) . .	7,3331 0 6
Office establishment (salaries, £662 8 6—Rent and taxes, £77 9 2—Stationery, &c. £81 10 5) . . .	811 8 1
Police and gatekeepers .	1356 9 11
Petty disbursements .	75 1 0
Rent	1840 1 10
Stationary engine and tunnel disbursement, new tunnel rope, £330 10 8—Coal £265 7 0—Wages £290 9 9—Repairs, oil, tallow, hemp, &c. £165 8 9 . . .	1051 16 2
Taxes and rates . .	1109 14 9
Wagon disbursements. Smiths' and joiners' wages, £586 6 7—Iron, timber, &c. £265 0 9—Canvass, paint, &c. for sheets, £155 10 10	1006 18 2
	£47,770 15 5
Deduct credits	1,112 4 1
	£46,658 11 4
Nett profits for six months	£28,048 4 9
Dividend per share of £100	4 0 0
Nett profit on Sunday travelling per share of £100 .	0 4 8

HALF-YEAR ENDING 31ST DECEMBER, 1832.

	Tons.
Merchandise between Livepool and Manchester . .	61,995
Ditto, to different parts of the road, including the Warrington and Wigan trade . .	6,011
Ditto, between Liverpool and Bolton . . .	18,836
Coals from various parts of the road to Liverpool or Manchester	39,940
Number of passengers booked in the Company's offices .	182,823
Number of trips of 30 miles performed by the locomotive engines with passengers .	3,363
Do. with goods . . .	1,679
Do. with coals . . .	211

Receipts.

Coaching department .	£43,120 6 11
General merchandise .	34,977 12 7
Coal department . .	2,804 3 4
	£80,902 2 10

Expenses.

Bad debt account . .	£81 6 0
Coach disbursements. Guards' and porters' wages £1173 19 6—Parcel carts and drivers' wages, £375 14 4—Materials for repairs, £464 1 9—Mens' wages, repairing £613 18 1—Gas, oil, tallow. &c. £232 11 7—Duty on passengers £985 19 1—Stationery and petty expenses £414 19 7	4261 3 11
Carrying disbursements. Salaries £1822 13 2.—Porters', &c. wages, £3925 7 4.—Gas, oil, tallow, cordage, &c. £296 11 7.—Repairs to jiggers, trucks, stations, &c. £398 3 11.—Stationery and petty expenses £540 13 5.	6983 9 5

Coal ditto	27	2	10
Cartage (Manchester)	2744	18	7
Charge for direction	295	1	0
Compensation (coaching)	209	15	11
Ditto (carrying)	150	19	11
Coach office establishment (Salaries £556 3 10—Rent and taxes, £75 16 2)	631	19	0
Engineering department	450	0	0
Interest	4555	15	7
Locomotive power. Fuel and watering, £3848 10 8.—Oil, tallow, hemp, &c. £661 1 9.—Materials for repairs, £3723 9 7.—Men's wages, repairing, £3352 16 2.—Engine and firemen's wages, £1060 11 6.	12,646	9	8
Law disbursements	118	3	8
Maintenance of way (wages **£3675 16** 5—Block, sleepers, chairs, &c. £2355 17 1 —Ballast, &c. £846 10 9)	6878	4	3
Petty disbursements	66	2	0
Rent	1246	5	0
Stationary, engine and tunnel disbursements (Coal, £209 15 3—Engine and brakemen's wages, £316 7 5—Repairs, gas, oil, tallow, &c. £326 14 7)	852	17	3
Taxes and rates	3483	18	2
Wagon disbursements. Smiths' and joiners' wages, £583 0 5—Iron, timber, &c. £350 12 10. — Canvass, paint, &c. for sheets, £31 0 0.	946	13	1
Office establishment (Salaries, £623 18 0—Rent £85 0 0—Stationery £18 9 0)	727	7	10
Police ditto	902	16	5
	£48,278	8	10

Nett profit for six months	£32,623	14	0
Dividend per share of £100	4	4	0
Nett profit on Sunday travelling per share of £100	0	4	0

HALF-YEAR ENDING 30TH JUNE, 1833.

	Tons.
Merchandise between Liverpool and Manchester	68,284
Ditto, to different parts of the line, including Warrington and Wigan	8,712
Ditto, between Liverpool, Manchester and Bolton	19,461
Coals from various parts, to Liverpool and Manchester	41,375
Total number of passengers booked in the company's offices	171,421
Number of trips of 30 miles performed by the locomotive engines, with passengers	3,262
Ditto with merchandise	2,244

Receipts.

Coaching department	£44,130	17	2
Merchandize ditto	39,301	17	3
Coal ditto	2,638	15	9
	£86,071	10	2

Expenses.

Advertising account	£50	8	7
Bad debt account	176	18	6
Coach disbursements. Guards and porters' wages, £1150 4 0—Parcel carts, horse keep and drivers' wages, £401 18 6—Materials for repairs, £383 15 11—Men's wages, repairing, £758 10 6—Gas, oil, tallow, cordage, &c. £324 4 0—Duty on passengers, £2466 15 4—Stationery and petty expenses, £236 15 6—Taxes on offices, stations, &c. £112 18 4	5,835	2	1
Carrying disbursements. Agents' and clerks' salaries, £1703 17 6—Porters' and brakesmen's wages, horse keep, &c. £4687 9 7 —Gas, oil, tallow, cordage, &c. £648 4 11—Repairs to jiggers, trucks, stations, &c. £405 13 1—Stationery and petty expenses, £336 9 0—Taxes, insurance, &c. on offices and stations, £798 1 8.	8,579	15	9
Coal disbursements	120	16	1
Cartage (Manchester)	2460	16	1
Charge for direction	252	0	0
Compensation (coaching)	38	1	2
Compensation (carrying)	1033	18	3
Coach office establishment (Agents' and clerks' salaries, £577 19 6—Rent and taxes, £102 17 1)	680	6	7
Engineering department	441	17	4
Interest	5,867	11	9

Locomotive power. { Coke and carting, £2795 4 5—Wages to coke fillers, and watering engines, £338 16 10—Gas, oil, tallow, hemp, &c. £760 15 2—Copper and brass tubes, iron, timber, &c. for repairs, £3290 8 8—Men's wages, repairing, £4115 0 8—Enginemen and firemen's wages, £892 4 4—Out-door repairs to engines, £943 6 8—Two new engines, "Leeds" and "Firefly," £1580 0 0 }	14,715	16	9
Maintenance of way (wages, £3648 18 5—Blocks, sleepers, chairs, &c. £2052 5 11 Ballast and draining, £1013 5 11)	6,714	9	3
Office establishment (Salaries, £624 19 0—Rent and taxes, £62 18 6—Stationery, &c. £56 19 5)	744	16	11
Police	950	4	7
Petty disbursements . .	70	0	0
Rent	601	15	8
Repairs to walls and fences .	296	4	0
Stationery engine and tunnel disbursements (Coal £155 8 1—Engine and brakemen's wages, £363 8 10—Repairs, gas, oil, tallow, &c. £340 15 11 . . .	859	12	10
Tax and rate	1,891	0	7
Waggon disbursements (Smiths' and joiners' wages, £598 3 1—Iron, timber, &c. £320 1 4—Cordage, paint, &c. for sheets £82 7 3)	1,000	11	8
Cartage (Liverpool) . .	18	4	6
	£52,900	9	1

Nett profit for six months	£33,171	1	1
Dividend per share of £100 .	4	4	0
Nett profit on Sunday travelling per share of £100 .	0	3	6

HALF-YEAR ENDING 31ST DECEMBER, 1833.

	Tons.
Merchandise between Liverpool and Manchester . .	69,806
Ditto, to and from different parts of the line, including Warrington and Wigan .	9,733
Ditto, between Liverpool, Manchester, and Bolton . .	18,708
Coal from various parts to Liverpool and Manchester .	40,134
Total number of passengers booked at the company's offices	215,071
Number of trips of 30 miles performed by the locomotive engines with passengers	3,253
Ditto, with merchandise .	2,587

Receipts.

Coaching department .	£54,685	6	11
Merchandise ditto .	39,957	16	8
Coal ditto	2,591	6	6
	£97,234	10	1

Expenses.

Advertising account . .	6	10	0
Bad debt account . . .	374	10	1
Coach disbursements. { Guards and porters' wages, £1168 4 6—Parcel carts, horse keep, and drivers' wages, £361 1 7—Materials for repairs, £689 12 6—Men's wages, repairing, £1041 1 3—Gas, oil, tallow, cordage, &c. £196 4 11—Duty on passengers, £3224 11 11—Stationery and petty expenses, £277 4 5—Taxes on offices, stations, &c. £116 0 8—Guards' clothes. £54 15 0. }	7,188	16	9
Carrying disbursements. { Agents' and clerks' salaries, £1728 16 9—Porters' and brakesmen's wages, horse keep, &c. £5006 6 10—Gas, oil, tallow, cordage, &c. £529 17 0—Repairs to jiggers, trucks, stations, &c. £366 9 11—Stationery and petty expenses, £429 5 1—Taxes and insurance on offices, &c. £456 17 7—Sacks for grain, £110 3 10. }	8,627	17	0
Coal disbursements . .	82	0	9
Cartage (Manchester) . .	3,173	18	0
Charge for direction . .	812	18	0
Compensation (coaching) .	142	4	8
Compensation (carrying) .	228	10	11
Coach office establishment			

	£	s.	d.
(Agents' and clerks' salaries, £602 6 8—Rent, £30)	632	6	8
Engineering department .	319	3	4
Interest	5,140	6	4
Locomotive power. {Coke and carting, £3197 4 4—Wages to coke fillers and waterers, £348 8 5—Gas, oil, tallow, hemp, cordage, &c. £865 14 9—Brass and copper, iron, timber, &c. for repairs, £3755 3 7—Men's wages, repairing, £4401 4 10—Engine and firemen's wages, £784 8 5—Out-door repairs to engines, £613 3 9.}	13,965	9	1
Maintenance of way. {Wages to plate layers, joiners, &c. £2937 19 2—Stone, blocks, sleepers, keys, chairs, &c. £2411 2 4—Ballasting and draining, £925 16 11—New rails, £150 16 3.}	6,425	14	8
Office establishment (Salaries, £607 2 0—Rent and taxes, £75 14 3—Stationery and printing, £22 7 8—Stamps, £17 2 3)	722	6	2
Police	1,022	7	6
Petty disbursements . .	61	19	6
Rent	603	10	8
Repairs to walls and fences .	665	3	4
Stationary engine and tunnnel disbursements, (Coal, £302 6 5—Engine and brakesmen's wages, £319 11 2—Repairs, gas, oil, tallow, &c £419 15 5—New rope for tunnel, £266 3 6) . .	1.307	16	6
Tax and rate	3,409	11	0
Wagon disbursements. {Smiths' and joiners' wages, £718 19 7—Iron, timber, castings, &c. £700 7 1—Cordage, paint, &c. £28 5 2—Canvass for sheets £163 6 5}	1,611	0	3
Cartage (Liverpool) . .	80	17	10
Law disbursement . .	300	3	9
	£56,350	1	9
Ne't profit for six months	£40,884	8	4
Dividend per share of £100	4	10	0
Nett profit on Sunday travelling per share of £100 .	0	5	3
Reserved fund formed in the six months . . .	4,088	8	10

HALF-YEAR ENDING 30TH JUNE, 1834.

	Tons.
Merchandise between Liverpool and Manchester . .	69,522
To and from different parts of the road, including Warrington and Wigan . .	15,201
Between Liverpool, Manchester and Bolton . . .	19,633
Coal to Liverpool and Manchester	46,069
Number of passengers booked at the Company's offices .	200,676
Number of trips of 30 miles performed by the locomotive engines with passengers .	3.317
Ditto with merchandise .	2,499

Receipts.

	£	s.	d.
Coaching department	£50.770	16	11
Merchandise ditto .	. 41,087	19	5
Coal ditto .	. 2.925	15	11
	£94,784	12	3

Expenses.

	£	s.	d.
Advertising account . .	£16	15	0
Bad debt ditto . . .	75	12	8
Coach disbursements. {Guards' and porters' wages, £1167 11 10—Parcel carts, horse keep and drivers' wages, £359 13 0—Materials for repairs, £1007 9 7—Mens' wages, repairing, £1221 15 5—Gas, oil, tallow, cordage, &c. £358 15 6—Duty on passengers, £3008 1 11—Stationery and petty expenses, £165 2 5—Taxes, insurance, &c. on offices and stations, £65 8 11}	7,353	18	7
Carrying disbursements. {Agents' and clerks' salaries, £1740 14 2—Porters' and brakesmen's wages, horse keep, &c. £5397 8 5—Gas, oil, tallow, cordage, &c. £708 17 4—Repairs to jiggers, trucks, stations, &c. £716 2 8—Stationery and petty expenses, £290 3 2—Taxes, insurance, &c. on offices and stations, £469 6 2}	9,322	11	3
Coal disbursements . .	45	1	0
Cartage (Manchester) . .	2,988	6	2
Charge for direction . .	289	16	0
Compensation (coaching) .	26	3	10
Compensation (carrying) .	645	6	0
Coach office establishment (Agents' and clerk's salaries, £615 1 11—Rent and taxes £63 1 1) . . .	678	3	0

Engineering department	352 10 0
Interest	5,546 4 0
Locomotive power. — Coke and carting, £2882 11 4—Wages to coke fillers and watering engines, £386 19 5—Gas, oil, tallow, hemp, &c. 881 18 4—Copper and brass tubes, iron, timber, &c. for repairs, £4140 19 6—Men's wages for repairing, £5432 8 8—Enginemen and firemen's wages, £836 14 3—A new engine, £700—Lathe engine, boiler and fixing for repairing sheds and watering stations, £380 6 4.	15,641 17 10
Law disbursements	100 0 0
Maintenance of way. — Wages and small materials, £4221 2 5—Stone, blocks, sleepers, &c. £1482 18 7—New rails and chairs, points, crossings, &c £3153 14 5—Ballast and leading, £493 2 0	9,350 17 5
Office establishment (salaries, £818 14 4—Rent and taxes, £58 8 0)	877 2 4
Police	1,016 18 1
Petty disbursements	60 0 0
Rent	363 11 11
Stationary engine and tunnel disbursements, (Coal, £327 12 1—Engine and brakesmen's wages, £385 7 0—Repairs, gas, oil, tallow, &c. £273 11 1)	986 10 2
Tax and rate	1,778 16 10
Wagon disbursements. — Smiths' and joiners' wages, £773 3 8—Iron, timber, &c. £723 12 4—Cordage, paint, &c. £109 19 2—Canvass for sheets, £240 0 0	1,851 15 2
Repairs to walls and fences	664 0 11
Cartage (Liverpool)	80 17 6
	£60,092 15 11
Net profit for six months	£34,691 16 4
Dividend per share of £100	4 10 0
Nett profit on Sunday travelling per share of £100	0 5 2

From the Railroad Journal.

LOCOMOTIVE ENGINES ON INCLINED PLANES.

Better and better.—It is with great pleasure that we lay before our readers, the following statement of a remarkable performance, handed to us by Mr. W. Norris of Philadelphia. We hope to see some one take up these facts and reconcile them to the theories hitherto adopted.

Meanwhile we will take a trip to the Columbia Road for the express purpose of witnessing a series of experiments upon that road with this engine.

"The Locomotive Steam Engine "George Washington" made for the State of Pennsylvania by William Norris of Philadelphia, was placed on the Columbia and Philadelphia Railroad on Saturday afternoon the 9th inst. On the following morning her powers were tested in ascending the Inclined Plane near Philadelphia, This plane is twenty eight hundred feet in length, with an ascent in that distance of one hundred and ninety-six feet, or at the rate of 369 feet to the mile, or seven feet rise in one hundred feet, or one foot in thirteen. The weight of the Engine is 14,930 lbs. only. The load attached weighed 19,200 lbs. including the weight of 24 persons who were on the Tender and Burthen Car. The Engine started immediately at the base, without a running start, and dragged up said load of 19,200 lbs. the above distance of 2800 feet in the space of two minutes and one second, or at the rate of $14\frac{3}{4}$ miles per hour; pressure on the boiler a fraction under 60 lbs. to the square inch. The Engine then descended the Plane with the same load at various speed, frequently stopping to test the security. The valves being reversed, or set for going ahead, and when it was desired to stop altogether, the steam was let on very slowly which brought her to a dead stand for a second or two, when she would immediately start up the grade. In this way, stopping and starting at pleasure, the time occupied in descending the 2800 feet, was from 12 to 15 minutes, thus testing the perfect security of her performance on the Plane. She again ascended the Plane with the same load and took her place on the road, the same morning, ready for use."

We insert the following with pleasure. The information both as correcting erroneous statements and as furnishing details is worthy of notice. We most earnestly recommend to the attention of "speculative minds" the concluding warning of Mr. Hassler's letter.

From the Morning Courier & N. Y. Enquirer.

In your paper of May 26th, 1836, you have inserted an article entitled "*Zinc in New Jersey*," inviting to enterprise, in procuring the metal from the ore. The statements are not entirely correct. Allow me therefore, to furnish the public with better information to prevent mistaken speculations.

The pure zinc lately produced, has lain for centuries in the ore in Jersey, Pennsylvania, Maryland, (and most likely in many other parts of the country,) just as the finest marble statutes are yet contained in the marble quarries of this country, needing only the artist to cut them out; but this cutting them out, enterprise and money alone will never effect; unless art also find its proper support to do it; and just as little will the speculation in money enterprise alone do it in zinc, without the necessary science of Metallurgy.

It will not only be interesting but instructive to give here the whole history of the production of the zinc in this country. As the whole was done *under my direction*, I may be allowed to be good authority in the matter.

Mr. John Hitz, Landamman, in the Grisons, (Switzerland,) a scientific miner, had many years ago produced the pure zinc from the Blende of Daros, which had never been done before, by a process entirely of his own invention, and different from all those practised in England, or on the continent of Europe. Soon his zinc sold at double price of the common material, and covered far around the roofs of the neighborhood. But the mine ran out, as it is termed, and about six years ago Mr. Hitz removed to this country with all his family. Passing with him through Philadelphia, about three years ago, Mr. Wetherhill showed us a specimen of Blende, from which he could not produce the metal. Mr. Hitz told me the procuring the pure zinc from it would be unquestionably successful.

In the last session of Congress, the construction of standard of weights and measures for the Custom Houses was ordered, and in continuance of my former operations of comparison, I was directed by the Secretary of the Treasury, to construct the same. Brass being the metal almost necessarily used for accurate Weights and Measures, it was a primary object to procure it of pure and good quality, for which the common spelter is not fit. It was therefore proper for me, to avail myself of the presence of Mr. Hitz, (then, and still occupied in the gold mines of Virginia,) to procure the pure zinc; this was done by his peculiar method, and by properly varying the process; with equal success upon the ores from the copper mines of Perkiomen (where the blende laid about as refuse,) from the ore (Franklinite,) of New Jersey, and from the High furnace near Frederic in Maryland. The "beautiful specimen obtained"!! from all three places together, are upwards of ten tons pure malleable metallic zinc, acknowledged far superior to the imported spelter, by all the importers and workmen in that line, who have seen it.

The amount already obtained being sufficient for the particular purpose of standards, the temporary furnace built for that purpose exists no more, as I needed the materials to build a brass casting furnace.

If any one should be willing to take up the subject in such a manner as to procure to the man who invented the process, and so successfully produced the results quoted, that reward of a solid establishment which is due to his knowledge and good character, I offer to serve as a means to obtain his co-operation; but I am in duty bound to warn mere speculators from engaging without that previous knowledge, which besides they will not find in any book, and trials will be ruinous, as proved by the previous failures. F. R. Hassler.

Washington City, May 28th, 1836.

We take pleasure in giving publicity to the following letter, from Mr. Beach, the Engineer who examined the route for the proposed Railroad from Morristown to Carpenter's Point:

(copy.)

Catskill, May 20, 1836.

Samuel Price, Esq. Branchville, Sussex Co., N. J.

Dear Sir—At the request of the Board

of Directors of the Morris and Essex Rail Road Ccmpany and a committee of the inhabitants of the county of Sussex, composed of yourself and others, I devoted Wednesday, Thursday and Friday of last week, in the examination of the proposed route for a railroad from Morristown through Sussex county, to Carpenter's Point, preparatory to making a survey of the same, which I shall probably be able to commence about the first of June next; but supposing that you would be glad to have my views of the subject previous to that survey, I embrace the first opportunity that I could possibly devote to that object, since I saw you, to communicate them.

On my way up, I passed through Rockaway, Berkshire Valley, thence on the east side of Hopatcong Lake, to Sparta, and thence via Lafayette to Branchville; from Branchville up the North Branch of Paulins Kill, through the gap of the Blue Mountain, called Culver's Gap, approaching the Delaware River a short distance above Milford, and along the same to Carpenter's Point. Returning, a more northerly route was persued. Leaving the Delaware at Carpenter's Point, ascending the slopes bounding the valleys of the Little and Big Flat Brooks, to Culver's Gap, from thence to Branchville, there is but one route. From Branchville, returning, two routes were examined, viz: via. Lafayette ahd Newtor, passing at or near Andover Furnace, Stanhope, Dever, Rockaway, to Morristown; the route is, generally, a feasible one for the advantageous location and construction of a railroad. From Carpenter's Point, ascending to the summit of the Blue Ridge, in Culver's Gap, there are no difficulties to be encountered, and I am confident that, on that section, no grade need be adopted exceeding forty feet der mile, ascent, and if desirable may be reduced below that. From the summit of the Blue Ridge at Culver's Gap, to Branchville, the grading will not be expensive, but a somewhat steeper grade must be adopted. From Branchville to Lafayette or Newton, and from thence to either Sparta or Andover, a level and cheap route can be obtained. Schooley's Mountain Ridge may be crossed from Sparta via the summit of the Morris Canal, on either side of Lake Hopatcong, to Dover; or from Andover Furnace, near Stanhope, to Dover, thence via Rockaway to Morristown, without encountering any objectionable steep grades, or very heavy expenditures in grading. Both the Blue Ridge and that of Schooley's Mountain and their vicinity, abounds with timber of an excellent quality for the superstructure of the road, which can be obtained at a reasonable or low rate. The country to be accommodated is rich in agricultural and mineral productions; it also abounds with water power, and has already numerous establishments for the manufacture of Iron in all its various forms.—There are also on the route several flouring mills, and other manufacturing establishments of various descriptions, all of which, with this road completed, will find upon it a cheap and expeditious transportation of their products to New-York market.

I am, respectfully, Your ob't. servant,
EPHRAIM BEACH, Civil Engineer.

From the New-York Farmer.

"Burlington, N. J., Weeding Hoe."—We are indebted to Mr. Thomas Collins, of Burlington, N. J., for specimens of the above named hoe. To us they appear well calculated to answer their purpose; and we shall be pleased to exhibit them at all times to those who may desire to provide themselves with similar utensils of the very best kind.

We give the description in his own language.

Mr. T. Collins, takes the libery of presenting to Mr. D. K. Minor, a set of "Burlington Weeding Hoes," and recommends the kind, from several years experience, as the best he has seen. Their principal use is for destroying weeds while small: in the hands of an experienced gardner, they make great despatch. Narrow sawblades, of the best quality as to temper, should be used; and the holes for rivets should be punched through the sawplate *without heating*, in order that the temper may not be injured.—The thinnest sawbaldes are to be preferred, as they can never be very dull, and may the sooner be sharpened. Half worn "*bucksaws*" will answer for this purpose.

Burlington, July 4th, 1836.